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US Army Corps of Engineers
Waterways Experiment Station

User's Reference Manual for a Three-Dimensional Numerical Hydrodynamic and Transport Model of the New York Bight

by S. Rao Vemulakonda

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Prepared for U.S. Army Engineer District, New York

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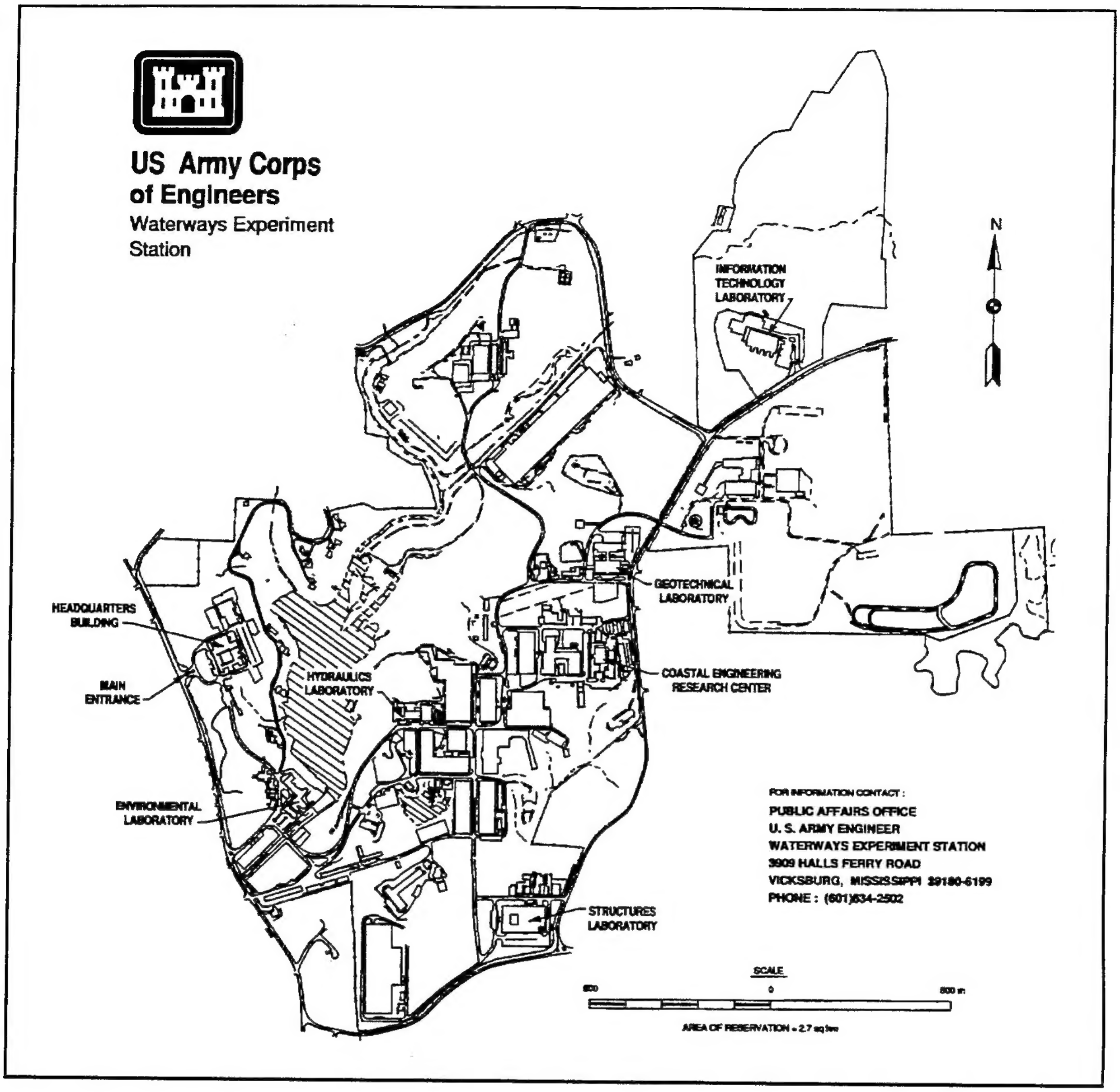

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Preface

The hydrodynamic modeling work described in this report was a part of the New York Bight Hydro-Environmental Modeling and Monitoring Study, authorized under Section 728 of the Water Resources Act of 1986. The study was performed during 1989-1993 for the U.S. Army Engineer District, New York (CENAN) by the U.S. Army Engineer Waterways Experiment Station (WES).

Hydrodynamic modeling was performed by personnel of the Coastal Engineering Research Center (CERC) of WES, under the general supervision of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Director and Assistant Director, respectively, of CERC. Direct supervision was provided by Mr. H. Lee Butler, Chief of the Research Division (RD), CERC, and overall WES Manager of the New York Bight project, Mr. Bruce A. Ebersole, Chief of the Coastal Processes Branch, RD, CERC, and Dr. Martin C. Miller, Chief of the Oceanography Branch, RD, CERC.

This report was prepared during 1993 by Dr. S. Rao Vemulakonda of CERC, and draws heavily on an earlier user's guide for the Chesapeake Bay hydrodynamic model (Johnson et al. 1991b).

CENAN points of contact during the study were Mr. John Tavalero, Ms. Patricia Barnwell-Pechko, Ms. Lynn Bocamazo, and Mr. Bryce Wisemiller. Their direction and assistance were invaluable. Field data for the 1975-1976 period were collected under the Marine EcoSystem Analysis (MESA) program and were made available under contract to WES by Dr. Andrew Stoddard of Creative Enterprises of Northern Virginia, Inc., and Dr. Gregory Han of Han & Associates, Inc.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, NON-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet/sec	0.02831685	cubic meters/sec
feet	0.3048	meters

1 Introduction

The New York Bight (NY Bight, Figure 1) is generally considered to be the area of the Atlantic Ocean extending from Cape May, New Jersey to Montauk Point, New York. Laterally, the NY Bight extends about 160 km from the coastline to the continental shelf break. It is a part of the Middle Atlantic Bight. Depths in the region vary from 3 m near Sandy Hook, New Jersey to 900 m in the Hudson Canyon, to over 2,000 m seaward of the continental shelf. Average depths are approximately 60 m. Circulation of water in the NY Bight is influenced by astronomical tides, meteorological forcing, flow from the Hudson-Raritan Estuaries, density gradients due to salinity and temperature variations, and bathymetric variations. Large-scale oceanic processes affecting the entire Middle Atlantic Bight may also play a role.

The NY Bight is of great importance for a variety of reasons, including navigation, recreation, seafood, and disposal of wastes and dredged materials. The adjacent coastal states are heavily populated and urbanized. With increasing population and industrialization come increasing pressures on the ecosystem. The environmental health and productivity of the NY Bight and the potential impacts of natural events and man-made projects on the Bight are therefore of great concern.

This report is a product of the NY Bight Study. The goal of this feasibility study, authorized under Section 728 of the Water Resources Act of 1986, was to identify a means of developing a comprehensive tool for effectively managing the resources of the NY Bight. A combined hydrodynamic-environmental modeling technique, used together with a monitoring plan and a geographic information system, was identified as the preferred approach to determine potential impacts to the NY Bight. This approach was adopted and its feasibility was demonstrated during the course of the study.

Since hydrodynamics is crucial to studying other aspects such as water quality, the three-dimensional hydrodynamic model CH3D-WES (Curvilinear Hydrodynamics in Three Dimensions) was selected for the NY Bight Study. This model was used previously by the Corps of Engineers and the Environmental Protection Agency in a highly successful joint study of the Chesapeake Bay (Johnson et al. 1991a). The model is capable of using a

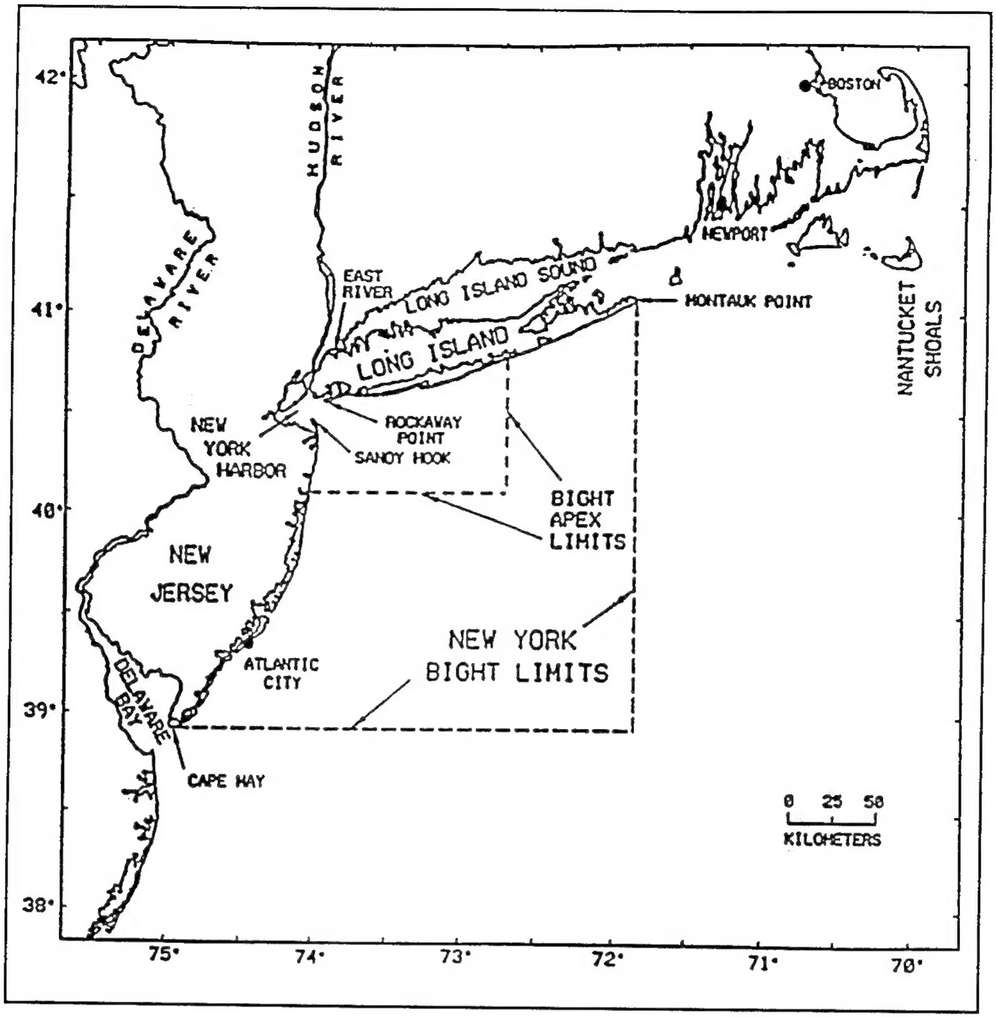

Figure 1. The New York Bight study area

boundary-fitted curvilinear grid in the horizontal to represent complex geometries. In the Chesapeake Bay application, a horizontal (z-) layer approach was used in the vertical direction. Compared to Chesapeake Bay, depths in the NY Bight vary considerably. Therefore, a sigma-layer version of the model was used. In this approach, the same number of layers are used in the vertical direction, in both deep and shallow parts of the study area. Because each sigma layer represents the same fraction of the total depth at a given location, sigma layers are curved. Even though the main interest of the study was in the Outer Bight, Long Island Sound and a part of the New York Harbor were included in the study area and numerical grid for the sake of completeness and to represent the hydrodynamic connections between the three areas.

The numerical grid selected for the study (Figure 2) has high resolution in areas of greater interest. It contains a maximum of 76 cells in the alongshore direction and 45 cells in the cross-shore direction. A total of 2,652 active horizontal (water) cells are used. The average horizontal grid resolution is

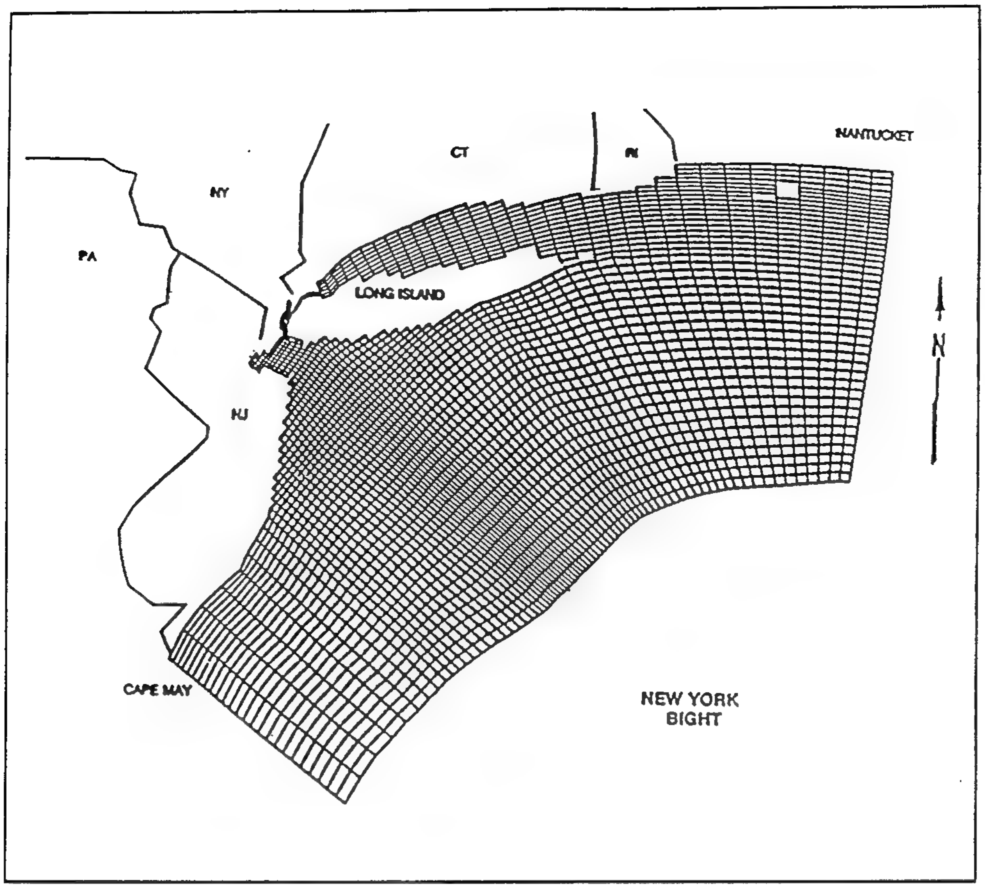

Figure 2. New York Bight computational grid

8 km in the alongshore direction with a minimum of 2 km in the Hudson Canyon and a maximum of 17 km near Cape May. Average resolution in the cross-shore direction is 6 km with a minimum of 200 m in the East River and a maximum of 8 km near the shelf break. The Hudson River is represented as a two-dimensional laterally-averaged body of water.

The hydrodynamic model was calibrated and verified for April and May 1976, using Marine EcoSystem Analysis (MESA) Program field data for surface elevations and currents. A 6-month-long extended validation was performed for the period April 1 - October 1, 1976, using MESA field data for salinity and temperature. Results from the simulation were used to drive successfully the Water Quality Model for the NY Bight. A demonstration of the hydrodynamic model was performed in Long Island Sound and East River for a 72-day period starting May 9, 1990, using the National Oceanic and Atmospheric Administration's (NOAA) field data on surface elevations, currents, salinity and temperature. All of these efforts are described by Scheffner et al. (1994).

The present report is a user guide to the NY Bight hydrodynamic model and should be used in conjunction with the report by Scheffner et al. (1994), which gives more details of the theory and implementation of the CH3D-WES

model, as well as numerical simulations performed and results obtained. The present report follows the following outline. After this introduction, the CH3D-WES model is briefly described in Chapter 2. Chapter 3 describes the structure of the model, the various subroutines used and the function of each. In Chapter 4, the setup of various input files is described, using an application of the New York Bight model as an example. Chapter 5 is a summary of the report. Appendix A gives model parameters and dimensions of various arrays used and Appendix B describes the format for the primary input file. Appendixes C-L give sample input files for the application given in Chapter 4.

2 CH3D-WES Hydrodynamic Model

The numerical hydrodynamic model CH3D-WES (Curvilinear Hydrodynamics in Three Dimensions - WES) was selected to provide detailed hydrodynamic flow field information for input to the water quality or environmental model. For convenience, most of the information on CH3D-WES furnished in this report is reproduced from Johnson et al. (1991b). The basic model (CH3D) was developed by Sheng (1986) for WES, but was extensively modified later in its application to the Chesapeake Bay Study. These modifications have consisted of implementing different basic numerical formulations of the governing equations as well as substantial recoding of the model to provide more efficient computing. As its name implies, CH3D-WES makes hydrodynamic computations on a curvilinear or boundary-fitted planform grid. Physical processes impacting circulation and vertical mixing that are modeled include tides, wind, density effects (salinity and temperature), freshwater inflows, turbulence, and the effect of the earth's rotation.

An adequate representation of the vertical turbulence is crucial to a successful simulation of stratification and destratification. A second-order algebraic turbulence model based upon the assumption of local equilibrium of turbulence is employed. The boundary-fitted coordinate feature of the model provides grid resolution enhancement necessary to adequately represent deep navigation channels and irregular shoreline configurations of the flow system. The curvilinear grid also permits adoption of accurate and economical grid schematization software. The solution algorithm employs an external mode, consisting of vertically averaged equations, which provides a solution for the free surface displacement and unit flow rates in two horizontal coordinate directions for input to the internal mode, which solves the full 3D equations.

Governing Equations

The governing partial differential equations are based on the following assumptions:

a. The hydrostatic pressure distribution adequately describes the vertical distribution of fluid pressure.

b. The Boussinesq approximation is appropriate.

c. The eddy viscosity approach adequately describes turbulent mixing in the flow.

The basic equations for an incompressible fluid in a right-handed Cartesian (x,y,z) coordinate system (Johnson et al. 1991b) are:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \tag{1}$$

$$\frac{\partial u}{\partial t} + \frac{\partial u^2}{\partial x} + \frac{\partial uv}{\partial y} + \frac{\partial uw}{\partial z} = fv - \frac{1}{\rho_o}\frac{\partial p}{\partial x} + \frac{\partial}{\partial x}\left(A_H \frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left(A_H \frac{\partial u}{\partial y}\right) + \frac{\partial}{\partial z}\left(A_v \frac{\partial u}{\partial z}\right) \tag{2}$$

$$\frac{\partial v}{\partial t} + \frac{\partial uv}{\partial x} + \frac{\partial v^2}{\partial y} + \frac{\partial vw}{\partial z} = -fu - \frac{1}{\rho_o}\frac{\partial p}{\partial y} + \frac{\partial}{\partial x}\left(A_H \frac{\partial v}{\partial x}\right) + \frac{\partial}{\partial y}\left(A_H \frac{\partial v}{\partial y}\right) + \frac{\partial}{\partial z}\left(A_v \frac{\partial v}{\partial z}\right) \tag{3}$$

$$\frac{\partial p}{\partial z} = -\rho g \tag{4}$$

$$\frac{\partial T}{\partial t} + \frac{\partial uT}{\partial x} + \frac{\partial vT}{\partial y} + \frac{\partial wT}{\partial z} = \frac{\partial}{\partial x}\left(K_H \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_H \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_v \frac{\partial T}{\partial z}\right) \tag{5}$$

$$\frac{\partial S}{\partial t} + \frac{\partial uS}{\partial x} + \frac{\partial vS}{\partial y} + \frac{\partial wS}{\partial z} = \frac{\partial}{\partial x}\left(K_H \frac{\partial S}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_H \frac{\partial S}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_v \frac{\partial S}{\partial z}\right) \tag{6}$$

$$\rho = \rho\,(T,S) \tag{7}$$

where

(u,v,w) = velocities in (x,y,z) directions
t = time
f = Coriolis parameter defined as $2\Omega \sin \phi$
Ω = rotational speed of the earth
ϕ = latitude
ρ = local fluid density
p = local fluid pressure
A_H, K_H = horizontal turbulent eddy coefficients
A_v, K_v = vertical turbulent eddy coefficients
g = gravitational acceleration
T = temperature
S = salinity
ρ_0 = average (reference) fluid density

Equation 4 implies that vertical accelerations are negligible and thus the pressure is hydrostatic. Equation 7, commonly known as the equation of state, relates the local density to the local temperature and salinity. In practice various forms of the equation can be specified. In the present model, the formulation given below is used:

$$\rho = P/(\alpha + 0.698P) \tag{8}$$

where

ρ = density in grams per cubic centimeter

$$P = 5890 + 38T - 0.375T^2 + 3S$$

$$\alpha = 1779.5 + 11.25T - 0.0745T^2 - (3.8 + 0.01T)S$$

and T is temperature in degrees Celsius and S is salinity in parts per thousand (ppt).

Non-Dimensionalization of Equations

The dimensionless forms of the governing equations are used to facilitate comparisons of the relative magnitudes of various terms in the governing equations. In what follows, for convenience, the same symbols as before are used to represent dimensionless variables.

External-Internal Modes

For computational efficiency, the solution scheme employs a "mode splitting" technique. In this procedure, Equations 1-4 are integrated over depth to yield a set of vertically integrated equations for the water surface ζ and unit flow rates U and V in the x and y directions (external mode). Thus, the time step for the rapidly varying external mode solution is limited by the surface gravity wave speed (the Courant condition). The major purpose of the external mode is to solve for the updated water-surface field and depth-integrated flows for input to the internal mode equations from which the vertical distributions of velocity, salinity, and temperature fields are computed. The time step for the slowly varying internal mode solutions is thereby removed from the Courant condition restriction and can be much larger than the external mode time step. The two modes together provide the full 3D solution.

Boundary-Fitted Equations

The CH3D-WES model utilizes a boundary-fitted or generalized curvilinear planform grid which can be made to conform to flow boundaries, providing a detailed resolution of the complex horizontal geometry of the flow system. This necessitates the transformation of the governing equations into boundary-fitted coordinates (ξ,η). If only the (x,y) coordinates are transformed, a system of equations similar to those solved by Johnson (1980) for vertically averaged flow fields is obtained. However, in the CH3D-WES model not only are the (x,y) coordinates transformed into the (ξ,η) curvilinear system but the velocity also is transformed such that its components are contravariant (i.e., perpendicular to the (ξ,η) coordinate lines). This is accomplished by employing the definitions below for the components of the Cartesian velocity (u,v) in terms of contravariant components $\bar{u}$ and $\bar{v}$.

$$
\begin{aligned}
u &= x_\xi \bar{u} + x_\eta \bar{v} \\
v &= y_\xi \bar{u} + y_\eta \bar{v}
\end{aligned}
\qquad (9)
$$

along with the following expressions for replacing Cartesian derivatives

$$f_x = \frac{1}{J}\left[(fy_\eta)_\xi - (fy_\xi)_\eta\right]$$

(10)

$$f_y = \frac{1}{J}\left[-(fx_\eta)_\xi + (fx_\xi)_\eta\right]$$

where f is an arbitrary variable and J is the Jacobian of the coordinate transformation defined as

$$J = x_\xi y_\eta - x_\eta y_\xi$$

With the governing equations written in terms of the contravariant components of the velocity, boundary conditions can be prescribed on the boundary-fitted grid in the same manner as on a Cartesian grid because $\bar{u}$ and $\bar{v}$ are perpendicular to the curvilinear cell faces (e.g., at a land boundary, either $\bar{u}$ or $\bar{v}$ is set to zero).

The vertical dimension is represented through the use of what is commonly referred to as sigma-stretched grid, illustrated in Figure 3. The vertical depth is discretized in a fixed number of layers, each layer equal in thickness to a fixed percentage of the local depth.

With both the Cartesian coordinates and the Cartesian velocity transformed, boundary-fitted equations for $\bar{u}$, $\bar{v}$, w, S, and T to be solved in each vertical layer are obtained.

Boundary Conditions

The boundary conditions at the free surface are

$$A_v\left(\frac{\partial \bar{u}}{\partial z}, \frac{\partial \bar{v}}{\partial z}\right) = \left(\tau_{s_\xi}, \tau_{s_\eta}\right)/\rho = \left(C\ W_\xi^2, C\ W_\eta^2\right)$$

$$\frac{\partial T}{\partial z} = \frac{Pr_v}{E_v} K\ (T - T_e) \tag{11}$$

$$\frac{\partial S}{\partial z} = 0$$

whereas the boundary conditions at the bottom are

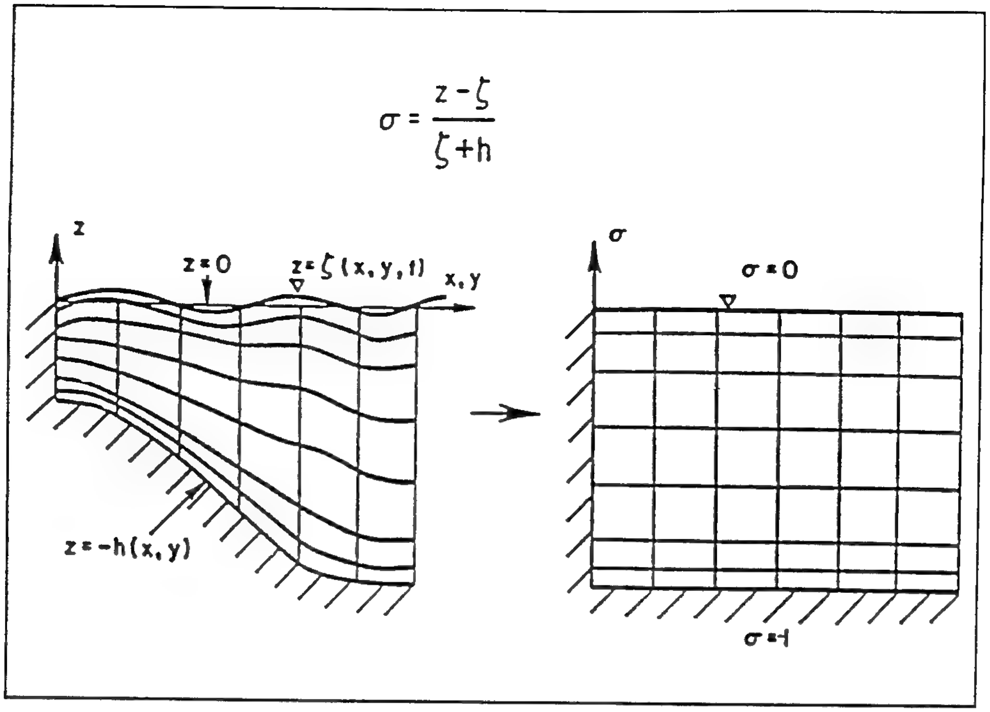

Figure 3. Sigma-stretched grid

$$A_v \left[\frac{\partial \bar{u}}{\partial z} , \frac{\partial \bar{v}}{\partial z} \right] = \left(\tau_{b_\xi} , \tau_{b_\eta} \right) / \rho$$

$$\frac{\partial T}{\partial z} , \frac{\partial S}{\partial z} = 0 \tag{12}$$

where

$\tau_{s\xi}, \tau_{s\eta}$ = wind stress components
C = surface drag coefficient
W = wind speed
Pr_v = Vertical Prandtl Number
E_v = Vertical Ekman Number
K = surface heat exchange coefficient
T_e = equilibrium temperature
$\tau_{b\xi}, \tau_{b\eta}$ = bottom shear stress components

The surface drag coefficient is computed according to Garratt (1977) as follows

$$C = (0.75 + 0.067\ W) \times 10^{-3} \tag{13}$$

with the maximum allowable value being 0.003. The surface heat exchange coefficient, K, and the equilibrium temperature, T_e, are computed from meteorological data (wind speed, cloud cover, wet and dry bulb air

temperatures, and relative humidity) as discussed by Edinger, Brady, and Geyer (1974).

Freshwater inflow and water temperature are prescribed along the shoreline where river inflow occurs, however, the salinity at the river boundary is specified according to a zero spatial gradient assumption (computed from the previous time step). At an ocean boundary, the water-surface elevation is prescribed along with time-varying vertical distributions of salinity and temperature. Specified values of salinity and temperature are employed during flood flow, whereas during ebb, interior values are advected out of the grid. The normal component of the velocity, the viscosity and diffusivity are set to zero along solid boundaries.

Initial Conditions

When initiating a run of CH3D-WES, the values of ζ, $\bar{u}$, $\bar{v}$, w, $\bar{U}$ and $\bar{V}$ are set to zero. Values of salinity and temperature are read from input files. These initial data are generated from prototype measurements at a limited number of locations. Once the values in individual cells are determined by interpolating from the field data, the resulting 3D field is smoothed. Generally, the salinity and temperature fields are held constant for the first few days of a simulation to allow the flow field solution to spin up.

Numerical Solution Algorithm

Finite differences are used to replace derivatives in the governing equations, resulting in a system of linear algebraic equations to be solved in both the external and internal modes. The external mode solution consists of the surface displacement and vertically integrated contravariant unit flows $\bar{U}$ and $\bar{V}$. All terms in the transformed vertically averaged continuity equation are treated implicitly whereas only the water-surface slope terms in the transformed vertically averaged momentum equations are treated implicitly. If the external mode is used only as a vertically averaged model, the bottom friction is also treated implicitly. Those terms treated implicitly are weighted between the new and old time-steps. Generally, a typical value of 0.55 for the time-weighting parameter yields stable and accurate solutions. The resulting finite difference equations are then arranged such that a ξ-sweep followed by an η-sweep of the horizontal grid yields the solution at the new time-step.

The internal mode consists of computations for the three velocity components $\bar{u}$, $\bar{v}$, and w, salinity, and temperature. The only terms treated implicitly are the vertical diffusion terms in all equations and the bottom friction and surface slope terms in the momentum equations. Values of the water-surface elevations from the external mode are used to evaluate the surface slope terms in the internal mode equations. As a result, the extremely

restrictive speed of a free-surface gravity wave is removed from the stability criteria for the internal mode solution. The second upwind differencing scheme of Roache (1976) is used to represent the convective terms in the momentum equations, whereas a spatially third-order scheme developed by Leonard (1979) (called QUICKEST) is used to represent the advective terms in the transport equations for salinity and temperature.

It should be noted that once the $\bar{u}$ and $\bar{v}$ velocity components are computed, they are slightly adjusted to ensure conservation of mass. This is accomplished by forcing the sum of $\bar{u}$ over the vertical to be the vertically averaged velocity $\bar{U}/H$ and the sum of $\bar{v}$ over the vertical to equal $\bar{V}/H$, where H is the total water depth.

Turbulence Parameterization

Vertical turbulence is handled by using the concept of eddy viscosity and diffusivity to represent the velocity and density correlation terms that arise from a time averaging of the governing equations. These eddy coefficients are computed from mean flow characteristics using a simplified second-order closure model originally developed by Donaldson (1973). The closure model has been further developed and applied to various types of flows by Lewellen (1977) and Sheng (1982, 1986, 1990). The procedure assumes local equilibrium of turbulence. For more details, the interested reader should refer to these references and to Johnson et al. (1991a).

Computational Grid

A staggered grid (Figure 4) is used in both the horizontal and vertical directions of the computational domain. In the horizontal direction, a unit cell consists of a ζ-point in the center ($\zeta_{i,j}$), a U-point to its "west" ($U_{i,j}$), and a V-point to its "south" ($V_{i,j}$). In the vertical direction, the vertical velocities are computed at the "full" grid points. Horizontal velocities, temperature, salinity, and density are computed at the "half" grid points (half vertical grid spacing below the full points).

Two arrays, NS and MS are set automatically by the model and used to flag the grid cells in the horizontal. The array NS indicates the condition of the "west" and "east" cell boundaries, whereas the array MS denotes the condition of the "north" and "south" cell boundaries (Figure 5).

The boundary-fitted grid shown in Figure 2 was developed to provide a high resolution representation of the complex geometry of the coupled New York Bight, New York Harbor, and Long Island Sound model domain. The computational grid contains a maximum of 76 cells in the alongshore direction and 45 cells in the offshore direction. There are 2,652 active horizontal grid cells and 10 vertical layers, resulting in 26,520 computational cells. The

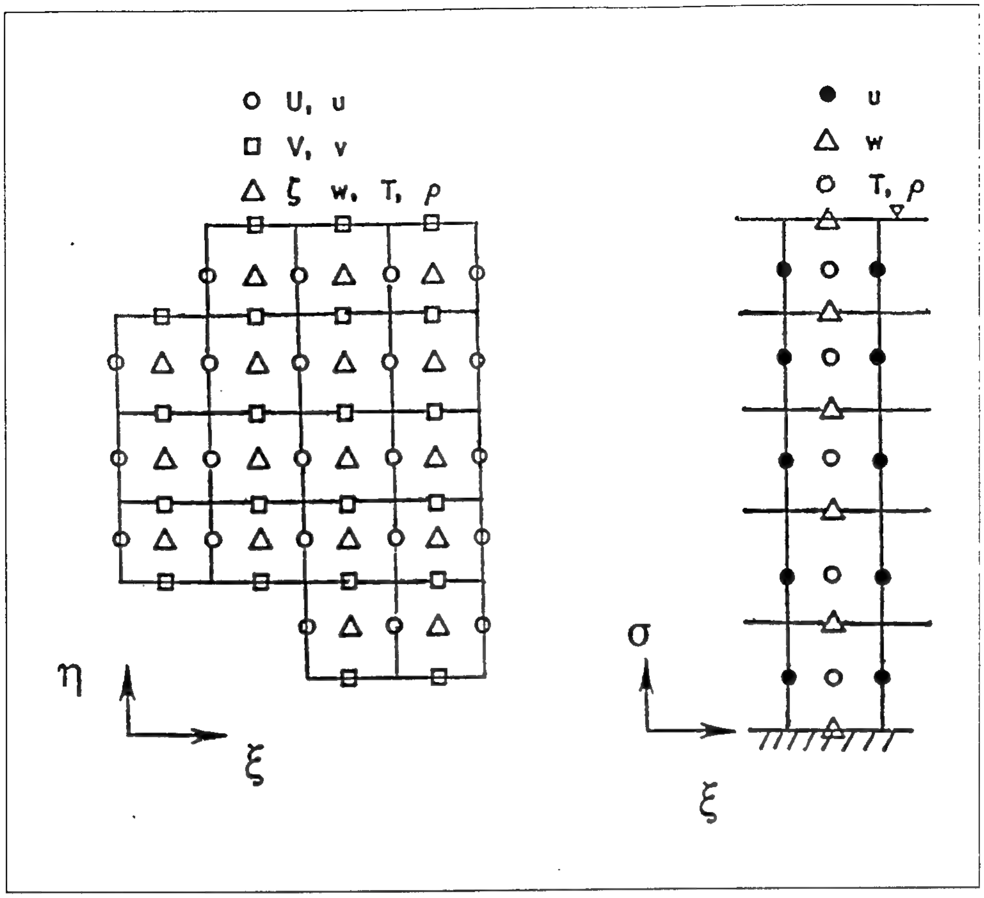

Figure 4. Staggered grid

Hudson river is parameterized as a two-dimensional, laterally-integrated body of water and modeled as a river boundary input to the Bight.

Depths, specified at the cell corners, were extracted from bathymetric data gathered from the National Oceanographic and Atmospheric Administration's (NOAA) nautical charts based on Mean Low Water. Although the resolution in Long Island Sound, New York-New Jersey Harbor and Hudson-Raritan estuary system is coarse for detailed study, the overall grid resolution is sufficient to provide insight into the circulation and transport processes in the Bight.

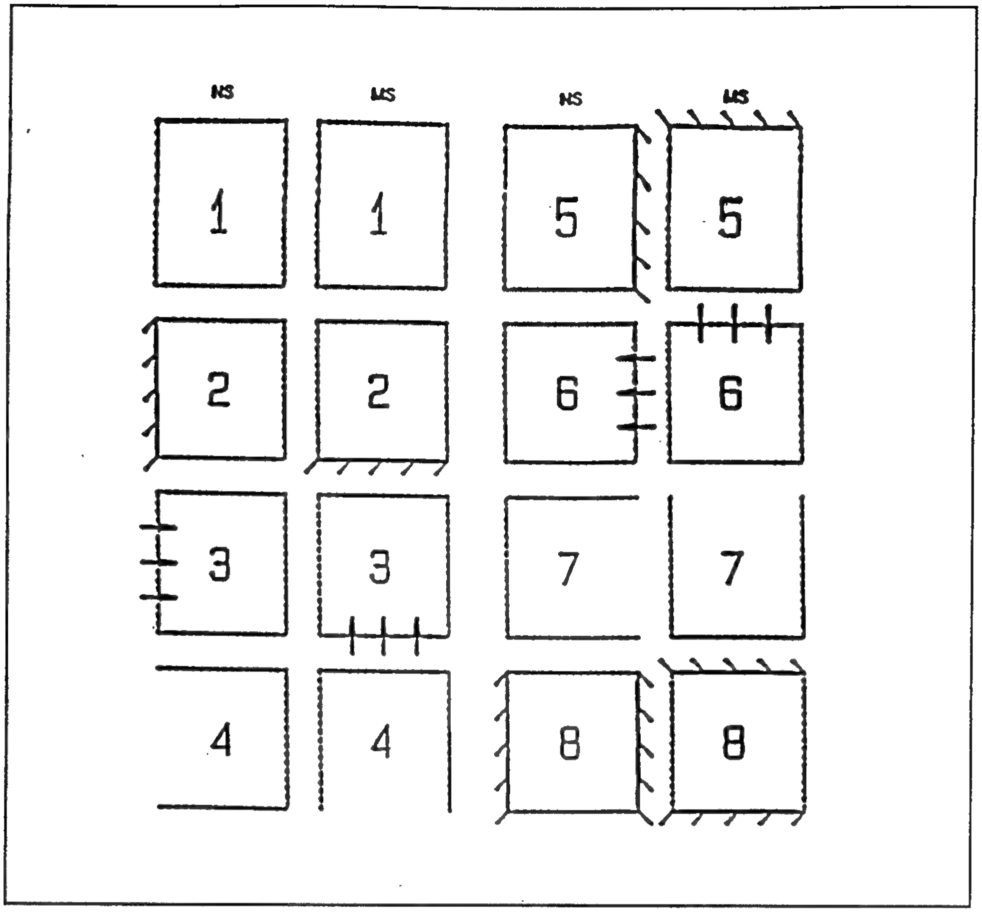

Figure 5. Typical values of NS and MS for different cell boundaries

3 Structure of the New York Bight 3D Hydrodynamic Model

The New York Bight model has a main program as well as several subroutines. Subroutines governing model setup are called from the main program while subroutines governing computations are called from subroutine CH3DM2. Each of these is listed below with a description of its function. Entry points in subroutines are also noted. Note that the UNIX operating system used on the Cray Y-MP computer and the Silicon Graphics' IRIS Indigo Workstation, where the CH3D-WES model is run, is sensitive to lower and upper case letters in file names, commands, etc. Two INCLUDE files, nyb.inc and ch3d.inc, are needed. They are used to set up parameters, dimensions of various arrays, and COMMON blocks. During model compilation, these files are inserted wherever the INCLUDE statements in the source code call for the files. These files are discussed in detail in Chapter 4, along with input files.

CH3D — The main program.

CH3DIR — Reads data from main input file, FILE 4 (see Appendix B), which controls computations, input, and output. Various constants are computed, and the vertical (σ-) layer thicknesses are set.

CH3DTR — Reads (x,y) coordinates (ft) and depths (ft) at the cell corners of the boundary-fitted grid from FILE 15 (ITRAN=2). The coordinates are then multiplied by the scale factor, XMAP, and divided by XREF to make them nondimensional. Subroutine BJINTR is called to provide the coordinate derivatives needed to compute the metrics of the transformation.

BJINTR — Computes various coordinate derivatives and sets the water depths HU(I,J) and HV(I,J) on the faces of each computational cell.

CH3DIH	Prints water depths, if requested by input data. Also, the water depths are made nondimensional by dividing by ZREF.
CH3DV1	Sets up flags for different grid cells to indicate land and water for later use in CH3DV2 for flow visualization.
CH3DV3	Similar to CH3DV1 for later use in CH3DV4 for salinity.
CH3DV5	Similar to CH3DV1 for later use in CH3DV6 for temperature.
CH3DND	Normalizes several variables and parameters, such as the Eckman number, Rossby number, time-step, etc.
CH3DII	Sets up the arrays of boundary flags that indicate the nature of computational cell boundaries. In addition, arrays controlling the computation of the convective terms in the momentum equations and the water surface cross-derivative terms are set up. One-dimensional channel cells are identified.
CH3DIF	Initializes various variables for a cold start run and opens time series output files for elevation, velocities, salinity, etc. as well as print and snapshot files. The hot start capability is not operational.
CH3DIV	The arrays related to water surface cross-derivatives created in CH3DII, contain logical values. Those arrays are used in this subroutine to create arrays containing numerical values. These arrays, i.e. AFV1(I, J), etc. are used to control computation of not only water surface cross-derivatives but other variables as well.
CH3DWS	Controls the reading of either wind speed or wind stress. If the wind speed is read, the stress is computed from Garratt's equation. ENTRY CH3DWT controls the reading of time-varying values and computations.

The subroutines above are called from CH3D in the sequence given. Before calling CH3DM2, which controls the computations, the initial salinity field is read from FILE 74. The initial temperature field is read from FILE 17 and made dimensionless.

CH3DM2	Final subroutine called from CH3D. All subroutines controlling the actual 3D computations are called from this subroutine in the order they appear below.

CH3DDP	Computes the total water depths from the latest water surface elevation field. ENTRY CH3DDM sets total water depths at the intermediate time level M and ENTRY CH3DDN sets total water depths at time level N.
CH3DTK	Reads equilibrium temperatures and surface heat exchange coefficients from FILE 19 and then transforms them into nondimensional form. ENTRY CH3DTB controls the reading of time-varying values and interpolation.
CH3DRI	Reads river inflows from FILE 13. ENTRY CH3DRV controls the reading of time-varying values and interpolation.
CH3DTI	Reads and initializes tidal boundary conditions from FILE 16. ENTRY CH3DTD updates boundary values.
CH3DSAI	Reads salinities and temperatures at tidal boundaries from FILE 76. ENTRY CH3DSAV controls the reading of time-varying values, interpolation, and conversion to nondimensional form.
CH3DTEI	Reads temperatures at river inflow boundaries from FILE 78. ENTRY CH3DTEV controls the reading of time-varying temperatures and interpolation.
WQMOUT	This is the main water quality module. It reads information on cell corner points and water quality boxes and computes box lengths, volumes, and flow face areas. ENTRY WQMCVOL computes the volumes for the first time and ENTRY WQTVD computes time-varying information and stores it for later input to the Water Quality Model.
PROC1	This subroutine called by WQMOUT performs Stokes' drift computations.
PTOUT	This is the main particle tracking module. It saves time-invariant information on grid characteristics first. ENTRY PTCVOL designates the output file number and ENTRY PTTVD saves time-varying information on wind stress, water depth, surface velocity, horizontal velocity and acceleration, and vertical velocity for later use by the Particle Tracking Model.
EK2, EK2V	These subroutines called by PTOUT compute the Ekman drift.

At this point, the loop over time is entered in CH3DM2 and each of the subroutines below is called, usually each time-step.

WQMCVOL	ENTRY in WQMOUT for computing initial box volumes.
PTCVOL	ENTRY in PTOUT for designating the output file.
CH3DDE	Computes water densities using Equation 8. The baroclinic terms in the momentum equations are then evaluated.
CH3DED	Sets up arrays that are then used in subroutine CH3DEZ for the computation of eddy viscosity and eddy diffusivity coefficients.
CH3DWT	ENTRY in CH3DWS for reading time-varying wind data.
CH3DTB	ENTRY in CH3DTK for reading time-varying equilibrium temperature and heat-exchange coefficient.
CH3DRV	ENTRY in CH3DRI for reading time-varying river flows.
CH3DTEV	ENTRY in CH3DTEI for reading time-varying temperatures at river inflow boundaries.
CH3DTD	ENTRY in CH3DTI for reading time-varying tide data.
CH3DSAV	ENTRY in CH3DSAI for reading time-varying salinity and temperature profiles at tidal boundaries.
CH3DDN	ENTRY in CH3DDP for assigning total water depths at time level N.
CH2DXY	Computes the vertically averaged flow field from the vertically averaged equations of motion.
CH3DDP	Computes the total water depths at time level N+1, using the water surface field computed in CH2DXY.
CH3DXYZ	Computes the 3D velocity field. Mass conservation is ensured by forcing the vertical sum of the horizontal components of the 3D velocity to match the vertically integrated values computed in CH2DXY.
CH3DDI	Computes the convective and diffusion terms in the momentum equations using the most recent computation results from CH3DDP and CH3DXYZ. These terms are then employed at the next time step in CH2DXY and CH3DXYZ.
CH3DSA	Computes the salinity field.
CH3DTE	Computes the temperature field.

CH3DBL	Checks the water surface elevations for the program "blowing up".
WQTVD	ENTRY in WQMOUT.
PTTVD	ENTRY in PTOUT.
CH3DOT	Controls the output printed and/or written to files for plotting. Output is in terms of physical dimensional variables. Subroutine CH3DC1 is called with ENTRIES CH3DC2, CH3DC3, CH3DC4, CH3DC5, CH3DC6, CH3DC7, CH3DC8, CH3DC9, CH3DCA, CH3DCC, CH3DCD, and CH3DCE. Each is described below.
CH3DC1	Provides dimensional water surface elevations.
CH3DC2	Provides dimensional physical vertically averaged velocity in *x*-direction.
CH3DC3	Provides dimensional physical vertically averaged velocity in *y*-direction.
CH3DC4	Provides dimensional physical horizontal velocity component in *x*-direction.
CH3DC5	Provides dimensional physical horizontal velocity component in *y*-direction.
CH3DC6	Provides dimensional physical vertical component of 3D velocity.
CH3DC7	Provides salinity.
CH3DC8	Provides dimensional temperature.
CH3DC9	Provides dimensional physical magnitude and direction of horizontal velocity.
CH3DCA	Provides dimensional physical horizontal components of 3D velocity at the centers of cells.
CH3DCC	Provides dimensional water density.
CH3DCD	Provides dimensional vertical eddy viscosity.
CH3DCE	Provides dimensional vertical eddy diffusivity.

After CH3DOT the following subroutines for visualization are called in CH3DM2 in the order shown:

CH3DV2	Saves time-varying flow information.
CH3DV4	Saves time-varying salinity information.
CH3DV6	Saves time-varying temperature information.

In subroutine CH3DOT, the following files are created for use in generating time series plots, vector plots, or contour plots.

FILE 21	For time series plots of dimensional water surface elevation at specified horizontal locations.
FILE 22	For time series plots of dimensional, Cartesian horizontal velocities (x and y directions) at cell centers at specified horizontal locations.
FILE 23	Geometry of study area (needed for plotting snapshots or contours).
FILE 24	For velocity vector plots and contour plots of surface elevation, salinity, temperature, etc.
FILE 25	For time series plots of discharges at specified horizontal ranges.
FILE 31	For time series plots of salinity at specified horizontal locations in all layers.
FILE 34	For time series plots of temperature at specified horizontal locations in all layers.
FILE 35	For time series plots of vertical eddy viscosity at specified horizontal locations in all layers.
FILE 36	For time series plots of vertical eddy diffusivity at specified horizontal locations in all layers.
FILE 37	For time series plots of density at specified horizontal locations in all layers.

The model creates the following additional output files.

FILE 42	For visualization of flow.
FILE 43	For visualization of salinity.
FILE 44	For visualization of temperature.
FILE 70	Geometric data and initial results for particle tracking.
FILE 71	Time-varying data for input to the Particle Tracking Model.
FILE 96	Time-varying data for input to the Water Quality Model.

4 Demonstration of the Setup of Input Files

To demonstrate the setup of input files (see the appendixes), portions of the input files are presented for an application in which the hydrodynamics of the New York Bight during April 1976 was simulated. This application represents the beginning of the long-term (6-month) model validation. Results from this application are presented by Scheffner et al. (1994).

INCLUDE Files

As previously indicated, two INCLUDE files, nyb.inc and ch3d.inc, are needed for compiling the model. Of these, nyb.inc is used to define variable array dimensions in the model for running a particular application, e.g., New York Bight 6-month simulation. It may be necessary for the user to change some of the parameters in nyb.inc. It is listed in Appendix A (page A-1). Parameters, whose values are set in nyb.inc, are used to dimension arrays in COMMON blocks in ch3d.inc and other arrays in the model. All the parameters appearing in nyb.inc are defined below. Of these, ICELLS, JCELLS, IJMAX, and KM have to be set exactly. The others can be greater than or equal to what is needed.

ICELLS	: Number of grid cells in the ξ-direction
JCELLS	: Number of grid cells in the η-direction
IJMAX	: The greater of ICELLS and JCELLS, plus 1
KM	: Number of σ-layers in the vertical
NSTATS	: Maximum number of gauge stations where information will be saved
NTIDES = 11	: Not used
NRIVRS	: Number of river boundaries used
NCNST = 37	: Maximum number of tidal constituents used (set to 37) - used only if tidal signals were generated using constituents - not operational.
NBNDS	: Number of open water boundaries used
NBARRS	: Number of interior thin-wall barriers

NPRWIN	: Number of print windows for printing model results
NSNAPS	: Number of snapshot windows where information is saved
NRANGS	: Number of ranges where discharge information is saved
NTIDFN	: Number of tide functions used
NTIDBN	: Number of tidal boundaries used
NTIDPT	: Maximum number of values in the input tide functions
NWINDS	: Number of input time-varying winds used for interpolating winds over grid (special for New York Bight application)
NROWS	: Maximum number of computational chains used in ξ-direction
NCOLS	: Maximum number of computational chains used in η-direction
KROWS	: Larger of NROWS and NCOLS, plus 1
NX8PTS	: Number of one-cell wide channel cells in ξ-direction
NY8PTS	: Number of one-cell wide channel cells in η-direction
ISSMAX = 10	: Not used
NPLPTS = 75	: Not used
NSDMAX = 10	: Not used
SPVAL	: A small value to which the vertical eddy coefficients, etc. are set as a default

In addition, the following parameters are used in connection with the water quality module in CH3D. They should be changed only if the Water Quality Model grid is changed.

NBP	: Number of water quality boxes in plan view.
NFP	: Number of flow faces in plan view.

A portion of the file ch3d.inc is listed in Appendix A (page A-2). This file does not have to be changed from application to application, but remains the same.

Basic Control Data

Appendix B lists the input variables and their format for the primary input file FILE 4. Appendix C gives a list of all the input files. Input data in FILE 4 for the application mentioned are listed in Appendix D. These data are in response to read statements presented in Appendix B. As can be seen, the computational time-step (DT) is 150 sec with a total of 17,280 time-steps (30 days) simulated (IT2=17280). Both temperature and salinity computations are made (ITEMP= -2 =ISALT), with the initially specified

fields frozen for the first 2,880 time-steps (ITSALT=2880). A time-varying wind (IWIND=5) is specified. There is one river (NRIVER=1), the Hudson. Eight tidal boundaries (TIDBND=8) and eleven tide functions (TIDFNO=11) are used to describe the time-varying tides at the boundaries by linear interpolation.

Freshwater Inflows

Daily-averaged freshwater flows specified at the Hudson River boundary are read from FILE 13. They are given in Appendix E for the first few days of the simulation. Input fields are day, hour, location of the river boundary, and the discharge (cfs).

Wind Speed

Wind data are read from FILE 14. Since IWIND = 5, time-varying wind velocity components (m/sec) are read and wind stresses are computed using Equation 11. For the April 1976 simulation, three wind fields are read (NWINDS = 3). These correspond to hindcast data obtained from three offshore stations of WES Wave Information Study. Inside CH3D-WES, wind velocity components for each computational cell are assigned by linear interpolation from the values read in for the three offshore stations. As can be seen in Appendix F, each line of input in FILE 14 consists of the day, hour, and the x and y components of the wind velocity for each of the three wind stations. Wind data at the three stations are presented in Appendix F only for the first few days in April 1976. Wind stresses computed in the x and y directions are transformed in the model into contravariant components.

Grid Coordinates and Water Depths

The x- and y- coordinates of the cell corners of the computational grid (Figure 2) and the corresponding depths (in feet) are read from FILE 15. The coordinates were generated using the grid generation program EAGLE (Thompson 1987a, 1987b). Landlocked points were assigned coordinate values of 9.0×10^{18}. Cell water depths were obtained by interpolation from bathymetric data digitized from National Ocean Service nautical charts for the New York Bight region. The format of these data for a few points is illustrated in Appendix G. The first line shows the title and the second line the number of points in the ξ and η directions. The x- and y- coordinates and depth of each point are then input starting with row 1 and moving from left to right, one point per line.

Tabular Tides

The tabular tide data are read from FILE 16. There are 8 tidal boundaries and the tide is interpolated at the boundary cells using 11 tide functions, as defined in the basic input file. Each string of input contains the month, day, year, hour and minute along with the corresponding values of the water surface elevation (cm) at the 11 tidal function point locations. Appendix H illustrates the form of these data for the first few hours of April 1976.

Initial Temperature and Salinity

FILES 17 and 74 are identical in form. FILE 17 contains the initial temperature field, whereas FILE 74 contains the initial salinity field. These files were generated by a computer program which uses a few observed values to assign values to the individual cells in each of the sigma layers. The resulting field is then smoothed in each horizontal direction in each layer and the smoothed field is written to either FILE 17 or FILE 74. Appendix I presents the initial temperature field for sigma layer 1.

Surface Heat Exchange Information

Daily averaged equilibrium temperatures and surface heat exchange coefficients computed from meteorological data at the John F. Kennedy Airport are read from FILE 19. As indicated in Appendix J, each input data line consists of the day and hour since the initiation of the simulation, the equilibrium temperature (deg C), and the surface heat exchange coefficient (cm/sec).

Tidal Boundary Salinity and Temperature

At tidal boundaries, the time-varying vertical distributions of salinity and temperature are read from FILE 76. As illustrated in Appendix K, these data are grouped in the following manner. The day and hour since the initiation of simulation is input on one line. It is followed by a line giving the (I,J) location of the tidal boundary cell and the corresponding vertical salinity distribution. The next line gives the same (I,J) location and the corresponding vertical temperature distribution. These distributions consist of values in each sigma layer, starting with the surface layer and going down to the bottom. This input is repeated for all the tidal boundary cells. Appendix K gives the input for the 61st day of simulation for a few boundary segments. Note information has to be repeated for cells common to two adjacent boundary segments.

River Temperature

River temperature data are read from FILE 78 (APPENDIX L). In the present case, there is only one river boundary, the Hudson. The values are estimated from available U.S. Geological Survey gauging station data. The first line contains the day and hour since initiation of the simulation. Next for each of the NRIVER rivers indicated in the input, the I and J cell indices are given followed by the temperature in different layers, starting from the surface and going down to the bottom. This is done in the order IJRSTR to IJREND for each river. The same procedure is followed for successive times.

5 Summary

The primary purpose of this report is to serve as a user guide for the New York Bight 3D hydrodynamic model. After a brief introduction to the New York Bight study region, the New York Bight feasibility study and the computational grid used, the report describes the main features of the CH3D-WES hydrodynamic model selected for the study. In Chapter 2, the basic governing equations are given followed by the boundary and initial conditions employed.

The report outlines the structure of the computer model in Chapter 3, listing the names of the various subroutines, their functions, and the calling sequence. This should help users who are interested in following the logic of the model. Also listed are various output files created by the model and their contents.

Chapter 4 of the report describes the INCLUDE files needed for defining grid dimensions, COMMON blocks , etc., and discusses the basic control data, and various input files for a specific application for the New York Bight study region covering the month of April 1976. A partial listing of the INCLUDE files is provided in Appendix A. The format of the primary input file is given in Appendix B followed in Appendix C by a list of all the input files required. The user guide function of the report is enhanced by demonstrating the various input files in Appendixes D-L for the specific application.

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Appendix A
Listing of INCLUDE Files

```
C
C====  INCLUDE FILE FOR NY BIGHT 1993; revised by Rao 7/29/93
C
C
      PARAMETER ( ICELLS = 76,  JCELLS = 45,   IJMAX  = 77 )
      PARAMETER ( KM     = 10,  K1M = KM - 1               )
C
      PARAMETER ( NSTATS = 40,  NTIDES = 11,   NRIVRS = 9  )
      PARAMETER ( NCNST  = 37,  NBNDS  = 11,   NBARRS = 9  )
      PARAMETER ( NPRWIN = 20,  NSNAPS = 20,   NRANGS = 20 )
      PARAMETER ( NTIDFN = 12,  NTIDBN = 11,   NTIDPT = 10000 )
      PARAMETER ( NWINDS = 3                               )
C
      PARAMETER ( NROWS  = 120, NCOLS  = 120,   KROWS = 121)
      PARAMETER ( NXBPTS = 10,  NYBPTS =  10               )
C
      PARAMETER ( IC1 = ICELLS + 1,  JC1 = JCELLS + 1     )
      PARAMETER ( IM  = ICELLS + 2,  JM  = JCELLS + 2     )
      PARAMETER ( ISSMAX = 10,       NPLPTS = 75          )
      PARAMETER ( NSDMAX  = 10,      SPVAL  = .1234E-6    )
C
C***** added PARAMETERS from Water Quality Module ! Rao 7/29/93
C***   Caution : Do not change unless Water Quality Model grid changes !!!
      PARAMETER (NBP = 3000, NFP = 6000)
C*****
C
```

```
c**** ch3d.inc for NY Bight project: last revised by Rao 7/29/93 - includes
c     particle tracking variables! added flags for saving info for water quality
c     (IWQ), particle tracking (IPT), and visualization (IVIS).
C --- INCLUDE FILE = CH3D.INC   Last revised on 2 MAY 91   KIM
C
      COMMON /BLK01/ HS(0:IM,0:JM),  HU(0:IM,0:JM),  HV(0:IM,0:JM),
     1               HSD(0:IM,0:JM)
      COMMON /BLK02/ UI(0:IM,0:JM), UIM(0:IM,0:JM), UIN(0:IM,0:JM)
      COMMON /BLK03/ VI(0:IM,0:JM), VIM(0:IM,0:JM), VIN(0:IM,0:JM)
      COMMON /BLK04/  S(0:IM,0:JM),  SM(0:IM,0:JM),  SN(0:IM,0:JM)
C
      COMMON /BLK05/ AHUU(0:IM,0:JM), AHUM(0:IM,0:JM), AHUN(0:IM,0:JM),
     1               AHVV(0:IM,0:JM), AHVM(0:IM,0:JM), AHVN(0:IM,0:JM),
     2               AHSS(0:IM,0:JM), AHSN(0:IM,0:JM), AHSM(0:IM,0:JM),
     3               AHUI(0:IM,0:JM), AHVI(0:IM,0:JM),
     4               AHSU(0:IM,0:JM,KM), AHSV(0:IM,0:JM,KM)
C
      COMMON /BLK07/ AFV1(0:IM,0:JM), AFV2(0:IM,0:JM), AFV3(0:IM,0:JM),
     1               AFV4(0:IM,0:JM), AFU1(0:IM,0:JM), AFU2(0:IM,0:JM),
     2               AFU3(0:IM,0:JM), AFU4(0:IM,0:JM)
C
      COMMON /BLK08/ DDSX(IC1,JC1), DDSY(IC1,JC1),
     1               DDDX(IC1,JC1), DDDY(IC1,JC1),
     2               DHSX(IC1,JC1), DHSY(IC1,JC1),
     3               DHTX(IC1,JC1), DHTY(IC1,JC1),
     4               DHUX(IC1,JC1), DHUY(IC1,JC1)
C
      COMMON /BLK09/ DIIX(IC1,JC1), DIIY(IC1,JC1)
      COMMON /BLK10/ XD1(IC1,JC1), XD2(IC1,JC1), XD3(IC1,JC1),
     1               YD1(IC1,JC1), YD2(IC1,JC1), YD3(IC1,JC1)
      COMMON /BLK11/ RIRHO(0:IM,0:JM,KM), DIRHO(0:IM,0:JM,KM)
      COMMON /BLK12/ THETA
      COMMON /AD077/ KU, KV
      COMMON /AD078/ BARU(0:IM,0:JM,KM), BARV(0:IM,0:JM,KM)
C
      COMMON /BLK16/ XU(IC1), XS(IC1), YV(JC1), YS(JC1), ALXREF, ALYREF
      COMMON /BLK17/ NS(0:IM,0:JM), IROW(NROWS), IU1(NROWS),
     $               IU2(NROWS),     ISW(NROWS),  NROW
      COMMON /BLK18/ MS(0:IM,0:JM), JCOL(NCOLS), JV1(NCOLS),
     $               JV2(NCOLS),     JSW(NCOLS),  NCOL
      COMMON /BLK07A/  KROW(KROWS), KU1(KROWS), KU2(KROWS), KKOL
      COMMON /BLK19/ NR(0:IM,0:JM), MR(0:IM,0:JM)
      COMMON /BLK20/ DT, DIT, DX, DY, DTDX, DTDY, DXI, DYI, D2XI, D2YI,
     $               DELT
      COMMON /BLK22/ DEDX(0:IM,0:JM), DEDY(0:IM,0:JM),
     1               FIIX(0:IM,0:JM), FIIY(0:IM,0:JM),
     2               FHDX(0:IM,0:JM), FHDY(0:IM,0:JM),
     3               CORX(0:IM,0:JM), CORY(0:IM,0:JM),
     5               XKOR(0:IM,0:JM,KM), YKOR(0:IM,0:JM,KM),
     4               TBX(0:IM,0:JM),  TBY(0:IM,0:JM),  AHO
      COMMON /BLK23/ IJRDIR(NRIVRS), IJRROW(NRIVRS), IJRSTR(NRIVRS),
     1               IJREND(NRIVRS), QRIVER(NRIVRS,IJMAX), NRIVER,
     2               IDAYA, IHOURA, IDAYB, IHOURB
      COMMON /BLK24/ IJBDIR(NBARRS), IJBROW(NBARRS), IJBSTR(NBARRS),
     $               IJBEND(NBARRS), NBAR
      COMMON /BLK25/ IJDIR(NBNDS), IJROW(NBNDS), IJSTRT(NBNDS),
     $               IJEND(NBNDS), ITIDE, IJLINE, NCG,NCONST
```

```
C
      COMMON /BLK26/ AMPW(JCELLS,NTIDES), AMPE(JCELLS,NTIDES),
     1              AMPS(ICELLS,NTIDES), AMPN(ICELLS,NTIDES),
     2              PHW(JCELLS,NTIDES),  PHE(JCELLS,NTIDES),
     3              PHS(ICELLS,NTIDES),  PHN(ICELLS,NTIDES),
     4              CAW(JCELLS,NTIDES),  CAE(JCELLS,NTIDES),
     5              CAS(ICELLS,NTIDES),  CAN(ICELLS,NTIDES),
     6              TP(NTIDES)
C
      COMMON /BLK27/ QRIVRA(NRIVRS,IJMAX), QRIVRB(NRIVRS,IJMAX)
      COMMON /BLK28/ IST(NSTATS), JST(NSTATS), NSTA, NFREQ
C-----------------------------------------------------------------
      CHARACTER*48 STATID, STATSA, STATS
C-----------------------------------------------------------------
      COMMON /BLK29/ STATID(NSTATS), STATSA(NSTATS), STATS(NSTATS)

      COMMON /BLK30/ ITBRK(10), RSPAC(10), ISPAC(10), JSPAC(10),
     $              ITBRK1, ITBRKI
      COMMON /BLK31/ ITRAN, IBD
      COMMON /BLK32/ TX(0:IM,0:JM), TY(0:IM,0:JM),
     1              TX1(0:IM,0:JM), TY1(0:IM,0:JM),
     2              TX2(0:IM,0:JM), TY2(0:IM,0:JM),
     3              TAUX(0:IM,0:JM), TAUY(0:IM,0:JM),
     4              TAUX1(0:IM,0:JM), TAUX2(0:IM,0:JM),
     5              TAUY1(0:IM,0:JM), TAUY2(0:IM,0:JM),
     6              WNDX1(NWINDS), WNDX2(NWINDS),
     7              WNDY1(NWINDS), WNDY2(NWINDS),WSPD(IC1,JC1),
     8              IDAY1, IHOUR1,TIME1, IDAY2, IHOUR2, TIME2,
     9              RHOAIR, WCONVF,TXF(0:IM,0:JM),TYF(0:IM,0:JM),
     .              TXFL(0:IM,0:JM),TYFL(0:IM,0:JM)
      COMMON /BLK33/ ITEST, IPA, IPB, ID, JPA, JPB, JD
      COMMON /BLK34/ FMAN(ICELLS,JCELLS), COR, GR, CTB, ROI, CZMULT
      COMMON /BLK35/ IGI, IGH, IGT, IGS, IGU, IGW, IGC, IGQ, IGP
      COMMON /BLK36/ IFI, IFD, IFDS,
     1              IWQ, IPT, IVIS
      COMMON /BLK37/ IT, IDAY0, IHOUR0, IMIN0, ISEC0, IT1, IT2, TIME,
     1              TIMES, TIME0, ITWQS, ITSALT, TIMSEC,TIMEA, TIMEB,
     2              TIMEC, TIMED, IDAYT1,IHRT1,IDAYT2,IHRT2,
     3              TIMET1,TIMET2, TEP2, TEX2, ITPTS
      COMMON /BLK38/ IWIND
      COMMON /BLK39/ IBTM, H1, H2, HADD, HMIN, SSS0, XMAP
      COMMON /BLK39A/ A1(IJMAX), A2(IJMAX), A3(IJMAX), A4(IJMAX),
     $              B1(IJMAX), B2(IJMAX), B3(IJMAX), B4(IJMAX),
     $              AA(IJMAX), BB(IJMAX), CC(IJMAX), DD(IJMAX)
C-----------------------------------------------------------------
      CHARACTER*4 NBX(ICELLS,JCELLS), NBY(ICELLS,JCELLS)
C-----------------------------------------------------------------
      COMMON /BLK40/ NBX, NBY
C
      COMMON /PFLAG/ IPSW, IPUIW, IPVIW, IPSSW, IPUW, IPVW,
     1              IPSG, IPUIG, IPVIG, IPSSG, IPUG, IPVG,
     2              IPWW, IPSAW, IPTEW, IPROW,
     3              IPWG, IPSAG, IPTEG, IPROG
C-----------------------------------------------------------------
      COMMON /TRN01/   GD(0:IM,0:JM,3)
      COMMON /TRN02/  G11(0:IM,0:JM,3), G12(0:IM,0:JM,3),
     $               G22(0:IM,0:JM,3)
```

```
      COMMON /TRN03/  H11(0:IM,0:JM,3), H12(0:IM,0:JM,3),
     $                H22(0:IM,0:JM,3)
      COMMON /TRN04/ D111(0:IM,0:JM,3), D112(0:IM,0:JM,3),
     $               D122(0:IM,0:JM,3)
      COMMON /TRN05/ D211(0:IM,0:JM,3), D212(0:IM,0:JM,3),
     $               D222(0:IM,0:JM,3)
      COMMON /TRN07/ FX11(0:IM,0:JM), FX12(0:IM,0:JM),
     $               FX21(0:IM,0:JM), FX22(0:IM,0:JM)
      COMMON /TRN08/ FY11(0:IM,0:JM), FY12(0:IM,0:JM),
     $               FY21(0:IM,0:JM), FY22(0:IM,0:JM)
      COMMON /TRN09/ X1U(IC1,JC1),X2U(IC1,JC1),Y1U(IC1,JC1),Y2U(IC1,JC1)
      COMMON /TRN10/ X1V(IC1,JC1),X2V(IC1,JC1),Y1V(IC1,JC1),Y2V(IC1,JC1)
      COMMON /TRN11/ X1C(IC1,JC1),X2C(IC1,JC1),Y1C(IC1,JC1),Y2C(IC1,JC1)
      COMMON /TRN12/ X1 (IC1,JC1),X2 (IC1,JC1),Y1 (IC1,JC1),Y2 (IC1,JC1)
C-----------------------------------------------------------------------
      COMMON /AREA01/ XCT(IC1,JC1), XCXX(IC1,JC1), XCYY(IC1,JC1),
     $                XCXXYY(IC1,JC1)
      COMMON /AREA02/ YCT(IC1,JC1), YCXX(IC1,JC1), YCYY(IC1,JC1),
     $                YCXXYY(IC1,JC1)
C-----------------------------------------------------------------------
C
C      COMMON /ADD01/ FMU(IC1), FMV(JC1), FMS(IC1), FMSV(JC1)
      COMMON /ADD02/ SG(KM), DZZ(KM), Z(KM), DZA(KM), DZB(KM)
      COMMON /ADD03/ U(0:IM,0:JM,KM), UN(0:IM,0:JM,KM), UM(0:IM,0:JM,KM)
      COMMON /ADD04/ V(0:IM,0:JM,KM), VN(0:IM,0:JM,KM), VM(0:IM,0:JM,KM)
      COMMON /ADD05/ W(0:IM,0:JM,KM), WW(0:IM,0:JM,KM), WN(0:IM,0:JM,KM)
     1      ,WT(0:IM,0:JM),U3AV(0:IM,0:JM,KM),V3AV(0:IM,0:JM,KM)
      COMMON /ADD06/ FBC(0:IM,0:JM),    FBCV(0:IM,0:JM),
     4               FI (0:IM,0:JM,KM), FJ   (0:IM,0:JM,KM),
     1               FRO(0:IM,0:JM,KM), FOABC(0:IM,0:JM,KM),
     2               FRQ(0:IM,0:JM,KM), FQABC(0:IM,0:JM,KM),
     3               FXYZ(0:IM,0:JM,KM)
      COMMON /ADD07/ C (0:IM,0:JM,KM), CA(0:IM,0:JM), CEQ(0:IM,0:JM),
     1               T (0:IM,0:JM,KM), TN (0:IM,0:JM,KM),
     2               SA(0:IM,0:JM,KM), SAAV(0:IM,0:JM,KM),
     3               SA0(0:IM,0:JM,KM),JS1(IM), JS2(IM), FSUM, SAINT
      COMMON /ADD7A/ IDAYS1, IHRS1, TIMES1, IDAYS2, IHRS2, TIMES2,
     1               SA1(NTIDES,IJMAX,KM), SA2(NTIDES,IJMAX,KM),
     2               TE1(NTIDES,IJMAX,KM), TE2(NTIDES,IJMAX,KM)
      COMMON /ADD7B/ IDYTE1, IHRTE1, TIMTE1, IDYTE2, IHRTE2, TIMTE2,
     1               TE3(NRIVRS,IJMAX,KM), TE4(NRIVRS,IJMAX,KM),
     2               SA3(NRIVRS,IJMAX,KM), SA4(NRIVRS,IJMAX,KM)
      COMMON /ADD08/ R(0:IM,0:JM,KM), RU(0:IM,0:JM,KM),RV(0:IM,0:JM,KM),
     1               RS(0:IM,0:JM), RUS(0:IM,0:JM), RVS(0:IM,0:JM)
      COMMON /ADD09/ GA (0:IM,0:JM,KM), GB (0:IM,0:JM,KM),
     1               GAB(   0:IM,0:JM), GBB(   0:IM,0:JM),
     2               RIA(0:IM,0:JM,KM), RIB(0:IM,0:JM,KM),
     3               VELGA(0:IM,0:JM,KM), VELGB(0:IM,0:JM,KM)
      COMMON /ADD10/ QQQ(0:IM,0:JM,KM), SL (0:IM,0:JM,KM)
      COMMON /ADD11/ UIX (0:IM,0:JM), UIY (0:IM,0:JM), UIC(0:IM,0:JM),
     1               VIX (0:IM,0:JM), VIY (0:IM,0:JM), VIC(0:IM,0:JM),
     2               UC (0:IM,0:JM,KM), VC (0:IM,0:JM,KM)
      COMMON /ADD12/ URES(0:IM,0:JM,KM), VRES(0:IM,0:JM,KM),
     1               WRES(0:IM,0:JM,KM),
     2               UIRES(0:IM,0:JM), VIRES(0:IM,0:JM),
     3               TBXRS(0:IM,0:JM), TBYRS(0:IM,0:JM)
```

```
      COMMON /ADD13/ UIW(0:JM), UIE(0:JM), VIS(0:IM), VINN(0:IM),
     1              SABE(KM), SABW(KM), SABS(KM), SABN(KM),
     2              TBE (KM), TBW (KM), TBS (KM), TBN (KM),
     3              CBE (KM), CBW (KM), CBS (KM), CBN (KM)
      COMMON /ADD14/ TXC  (0:IM,0:JM),  TYC  (0:IM,0:JM),
     1              TX2C (0:IM,0:JM),  TY2C (0:IM,0:JM),
     2              FRICX(0:IM,0:JM),  FRICY(0:IM,0:JM),
     3              BZO  (0:IM,0:JM),  BZOU (0:IM,0:JM)
C
      COMMON /INP01/ XDIST(2*IM+1), XSLOPE(2*IM+1),
     1              YDIST(2*JM+1), YSLOPE(2*IM+1),
     2              XKAPPA(37,NTIDES), XLONG(NTIDES)
      COMMON /INP02/ AV1, AV2, BZ1, CO, FKB, ZREFBN, ZREFTN, OMEGA
      COMMON /INP03/ ICC1, ICC2, JCC1, JCC2, ID1, ID2, JD1, JD2,
     1              IGRID, TOO, TWE, TWH,
     2              TZ1, XDAY, XHOUR, XYEAR, XMONTH
C
      COMMON /ADD50/ IVER, ICON, IUBO, IBL, IBR, JBM, JBP, CREF, CMAX
      COMMON /ADD51/ XREF, ZREF, UREF, WREF, SREF, ROO, ROR, TO, TR
      COMMON /ADD52/ IEXP, IAV, AVR, AHR, APA, AVREF, AVM, AVM1
      COMMON /ADD53/ IVLCY, ISALT, ICC, IFA, IFB, IFC
      COMMON /ADD54/ IRD, IW, IWR, ICI, IR4, IWC,ICONC, IWS,IREAD,IRUN
      COMMON /ADD55/ DZ, EH, EV, H, FR, FR2, FRD, FRD2, RB, RBV, BETA,
     1              SZ, TAUR, WTS, WTU, WTV
      COMMON /ADD56/ IP1, IP2, IP3, IPU, IPW, KPA, KPB, KD,
     1              IGL, IGRI, IGTB, IRES, TRES
      COMMON /ADD57/ ITEMP, TQ(0:IM,0:JM), BVR, S1, S2, PR, PRV
      COMMON /ADD58/ NRANGE, KST(NSTATS)
      COMMON /ADD59/ FM1, FM2, ZTOP, BSC, ZAB, TRI1, TRI2,SQU1, SQU2,
     1              Q2R1, WWX
      COMMON /ADD60/ ISMALL, ISIE, ITB
      COMMON /ADD61/ ATB, BTB, STB, VCO, WK, ZREFB, ZREFT, ZOT,
     1              SLMIN, QQMIN
      COMMON /ADD62/ QCUT, ICUT, GAMAX, GBMAX, FZS, KSMALL
      COMMON /ADD63/ SSMAX, ISMAX, JSMAX, UUMAX, IUMAX, JUMAX, KUMAX,
     1                                VVMAX, IVMAX, JVMAX, KVMAX
      COMMON /ADD64/ DHX(0:IM,0:JM), DHY(0:IM,0:JM)
      COMMON /ADD65/ IXB(NXBPTS), IYB(NXBPTS), NXB,
     1              JXB(NYBPTS), JYB(NYBPTS), NYB
      COMMON /ADD66/ NISS, ISS(ISSMAX),JSS(ISSMAX),
     1              NDEPTH  (NSDMAX), TDEPTH(NSDMAX),
     2              ZDEPTH  (NSDMAX,ISSMAX),
     3              ZSAL    (NSDMAX,ISSMAX), SX(KM,ISSMAX)
      COMMON /ADD67/ SX(0:IM,0:JM), SY(0:IM,0:JM)
      COMMON /ADD68/ ACST(NCNST), PCST(NCNST)
      COMMON /ADD69/ TEP(0:IM,0:JM), TEX(0:IM,0:JM), HN(0:IM,0:JM)
C
      COMMON /MODBJ/ AREA(0:IM,0:JM), DFAC(IC1,JC1)
C
C**** added for visualization  Rao 7/29/93
      INTEGER VISSTRF, VISENDF,VISINTF, VISSTRS, VISENDS, VISINTS,
     1        VISSTRT, VISENDT, VISINTT
      COMMON /VIS/ VISSTRF, VISENDF, VISINTF, VISSTRS, VISENDS,
     1            VISINTS, VISSTRT, VISENDT, VISINTT
C****
```

Appendix B
List of Input Data in File 4

DUMMY
TITLE   Run descriptor (Format A80)

DUMMY
IT1, IT2, DT, ISTART, ITEST, ITSALT (2I8,F8.0,4I8)

IT1	; Starting time step (always set = 1)
IT2	; Ending time step
DT	; Computational time step in sec
ISTART = 0	; Cold start
> 0	Hot start (not operational)
ITEST = 0	; No diagnostic output
> 0	; Diagnostic output
ITSALT	; Number of time steps after which salinity and temperature computations are initiated

DUMMY
WPRCRD (9I8,A8)

WPRCRD	; Number of print control lines which follow

DUMMY
WXCEL1, WXCEL2, WYCEL1, WYCEL2, WZCEL1, WZCEL2, WPRINT, WPRSTR, WPREND, WPRVAR (9I8,A8)

If WPRCRD > 0, WPRCRD lines have to be furnished below.

WXCEL1	; Starting ξ-cell index
XCEL2	; Ending ξ-cell index
WYCEL1	; Starting η-cell index
WYCEL2	; Ending η-cell index
WZCEL1	; Starting sigma layer index
WZCEL2	; Ending sigma layer index
WPRINT	; Printing interval (number of time steps)
WPRSTR	; Time step when printing starts
WPREND	; Time step when printing ends
WPRVAR	; Character string indicating variables printed

Note : The following characters are used in WPRVAR for designating different variables.

E : Surface elevation (cm)
X : X-direction unit flow rate (cm^2/sec)
Y : Y-direction unit flow rate (cm^2/sec)
U : X-direction velocity (cm/sec)
V : Y-direction velocity (cm/sec)
W : Z-direction velocity (cm/sec)
S : Salinity (ppt)
T : Temperature (deg C)
A : Average velocity magnitude (cm/sec) and direction (measured clockwise from the true North, deg)

DUMMY
SNPCRD (9I8,A8)
SNPCRD ; Number of snapshot control lines to follow

DUMMY
SXCEL1, SXCEL2, SYCEL1, SYCEL2, SZCEL1, SZCEL2, SNPINT, SNPSTR, SNPEND, SNPVAR (9I8,A8)

If SNPCRD > 0, SNPCRD lines have to be furnished below.

SXCEL1 ; Starting ξ-cell index
SXCEL2 ; Ending ξ-cell index
SYCEL1 ; Starting η-cell index
SYCEL2 ; Ending η-cell index
SZCEL1 ; Starting sigma layer index
SZCEL2 ; Ending sigma layer index
SNPINT ; Snapshot interval (number of time steps)
SNPSTR ; Time step when snapshots start
SNPEND ; Time step when snapshots end
SNPVAR ; Character string indicating snapshot variables (same notation is used as in WPRVAR)

DUMMY
NRANG (9I8,A8)
NRANG ; Number of ranges for computing discharges

DUMMY
RANGDR, RPOS1, RPOS2, RPOS3, RRNAME (7X,A1,3I8,A45)

If NRANG > 0, NRANG lines have to be furnished below.

RANGDR ; Range direction (X for ξ and Y for η)
RPOS1 ; ξ (η) cell index of range line
RPOS2 ; Starting η (ξ) cell index for range
RPOS3 ; Ending η (ξ) cell index for range
RRNAME ; Range descriptor (name)

DUMMY

IGI, IGH, IGT, IGS, IGU, IGW, IGC, IGQ, IGP (10I8) : Printout flags. A value of 1 turns printing on and 0 turns it off.

IGI	; Print arrays such as NS, MS, NR, MR, etc.
IGH	; Print all depth arrays
IGT = 0	;
IGS = 0	; Print restart arrays
IGU = 0	;
IGW= 0	;
IGC	; Print grid coordinates and depths
IGQ = 0	;
IGP	; Save grid information in FILE 23 for plotting snapshots

DUMMY

XREF, ZREF, UREF, COR, GR, RO0, ROR, T0, TR (10F8.0)

XREF	; Reference horizontal grid distance (Maximum horizontal dimension divided by number of cells in that direction, cm)
ZREF	; Reference depth (average depth in cm)
UREF	; Reference horizontal velocity (average velocity in cm/sec)
COR	; Coriolis parameter
GR	; Gravitational acceleration (cm/sec^2)
RO0	; Minimum density expected (gm/cc)
ROR	; Reference density (maximum expected) (gm/cc)
T0	; Minimum temperature (Celsius)
TR	; Reference temperature (maximum expected) (Celsius)

DUMMY

THETA (10F8.0)

THETA	; Time level weighting factor in computations (A value of 1.0 was used in the Bight model)

DUMMY

ITEMP, ISALT, ICC, IFI, IFA, IFB, IFC, IFD (10I8)

ITEMP	= 0	; No computation of temperature
	=-1	; Compute temperature (use daily equilibrium temperature as river boundary temperature)
	=-2	; Compute temperature (use time-varying temperature as river boundary temperature)
ISALT	= 0	; No computation of salinity
	=-2	; Compute salinity, setting salinity and temperature at tidal boundaries
ICC	= 0	; Not used
IFI	= 1	; Compute nonlinear (inertia) terms
	= 0	; No computation of nonlinear terms
IFA	= 0	; Not used
IFB	= 0	; Not used

```
IFC     = 0     ; Not used
IFD     = 1     ; Compute horizontal diffusion terms
        = 0     ; No computation of horizontal diffusion terms

DUMMY
IVIS, IWQ, IPT (10I8)
IVIS    = 1     ; Save information for subsequent visualization
        = 0     ; Information for visualization is not saved
IWQ     = 1     ; Save information for input to Water Quality Model
        = 0     ; Information for input to Water Quality Model is
                  not saved
IPT     = 1     ; Save information for input to the Particle
                  Tracking Model
        = 0     ; Information for input to the Particle Tracking
                  Model is not saved

DUMMY
VISSTRF, VISENDF, VISINTF (10I8) (to be supplied only if IVIS=1)
VISSTRF         ; Starting time step (integer) for saving
                  information for flow (surface elevation and
                  horizontal velocities)
VISENDF         ; Ending time step (integer) for saving
                  information for flow (surface elevation and horizontal
                  velocities)
VISINTF         ; Time step interval (integer) for saving flow
                  information

DUMMY
VISSTRS, VISENDS, VISINTS (10I8) (to be supplied only if IVIS=1)
VISSTRS         ; Starting time step (integer) for saving
                  salinity information
VISENDS         ; Ending time step (integer) for saving
                  salinity information
VISINTS         ; Time step interval (integer) for saving
                  salinity information

DUMMY
VISSTRT, VISENDT, VISINTT (10I8) (to be supplied only if IVIS=1)
VISSTRT         ; Starting time step (integer) for saving
                  temperature information
VISENDT         ; Ending time step (integer) for saving
                  temperature information
VISINTT         ; Time step interval (integer) for saving
                  temperature information
```

Note: The ending time step should be greater than the starting time step. If you want to save only some visualization information (e.g., flow) but not others (e.g., salinity), set VISSTRF and VISENDF to realistic values corresponding to the simulation but set VISTRS and VISENDS to values > IT2.

DUMMY
BVR, S1, S2, PR, PRV, TWE, TWH, FKB, TQ0 (10F8.0)

BVR	= 1.0	; Reference turbulent thermal eddy diffusivity (not used)
S1	= 10.0	; Empirical constant used in computation of simple variable vertical eddy viscosity
S2	= 3.33	; Empirical constant used in computation of simple variable vertical eddy diffusivity
PR	= 1.	; Turbulent Prandtl number
PRV	= 1.	; Vertical turbulent Prandtl number
TWE		; Temperature in the epilimnion (for computing initial conditions)
TWH		; Temperature in the hypolimnion (for computing initial conditions)
FKB		; Vertical grid index of the initial thermocline location (for computing initial conditions)
TQ0	= 0.0	; Initial surface heat flux (cal/cm^2/sec)

Note: The initial conditions computed using TWE, TWH, and FKB are overridden by FILE 17.

DUMMY
IVER, ICON, IUBO, IBL, IBR, JBM, JBP (10I8)

IVER = 2
ICON = 3
IUBO = 0
IBL = 1
IBR = ICELLS
JBM = 1
JBP = JCELLS

DUMMY
CREF, CMAX, C0 (10F8.0)

CREF = 1.
CMAX = 100.
C0 = 0.

DUMMY
ICC1, ICC2, JCC1, JCC2, ID1, ID2, JD1, JD2 (10I8)

ICC1 = 0
ICC2 = 0
JCC1 = 0
JCC2 = 0
ID1 = 0
ID2 = 0
JD1 = 0
JD2 = 0

DUMMY
IEXP, IAV, AVR, AV1, AV2, AVM, AVM1, AHR (2I8,8F8.0)

IEXP : Vertical eddy coefficient flag
IEXP = 0 ; Constant eddy coefficient. Set ISPAC(9)=0.
=-1 ; Munk-Anderson type first order turbulence model. Richardson number dependent eddy coefficient with length scale linearly increasing from bottom and surface
=-2 ; Munk-Anderson type first order turbulence model. Richardson number dependent eddy coefficient with length scale linearly increasing from bottom to surface
=-3 ; Second-order turbulence model

Note: For IEXP < 0, set ISPAC(9)=1.

IAV : Reference vertical eddy viscosity flag.
IAV = 0 ; Input parameter AVR is used as reference eddy viscosity
= 1 ; Reference vertical eddy viscosity is computed from AV1+TXY*AV2, where TXY is the total wind stress and AV1 and AV2 are input parameters (applies only for IWIND=0 and IWIND=1)
AVR ; Reference vertical eddy viscosity (cm^2/sec)
AV1 ; Background vertical eddy viscosity when wind is zero (cm^2/sec).
AV2 ; If IAV=1, unstratified vertical eddy viscosity is computed from AV1+TXY*AV2.
AVM ; Minimum allowable vertical eddy viscosity (cm^2/sec)
AVM1 ; Minimum allowable vertical eddy diffusivity (cm^2/sec)
AHR ; Reference horizontal eddy viscosity or diffusivity (cm^2/sec)

DUMMY
FM1, FM2, ZTOP, SLMIN, QQMIN (10F8.0)

FM1 ; Parameter in Richardson number dependent eddy viscosity
FM2 ; Parameter in Richardson number dependent eddy diffusivity
ZTOP ; Distance between the top of the computational domain and the free surface (cm). Used in computing turbulence length scale.
SLMIN ; Minimum value of turbulence macroscale (cm)
QQMIN ; Minimum value of turbulent kinetic energy ($gm/cm/sec^2$)

DUMMY
ICUT, KSMALL, QCUT, GAMAX, GBMAX, FZS (2I8,8F8.0)

ICUT = 0 ; Eddy coefficients constant below halocline
= 1 ; Eddy coefficients computed below halocline
KSMALL ; Number of times eddy viscosity/diffusivity in turbulence model are smoothed (e.g., 5)
QCUT ; Coefficient in second-order turbulence model (0.15 - 0.25)
GAMAX ; Maximum value of eddy viscosity (cm^2/sec)
GBMAX ; Maximum value of eddy diffusivity (cm^2/sec)
FZS ; Turbulence scale is not allowed to exceed the product of FZS and the depth

DUMMY
IWIND, TAUX, TAUY (I8,5F8.0)

IWIND = 0 ; Steady and uniform wind stress
= 1 ; Steady and uniform wind speed
= 2 ; Steady and space variable wind stress
= 3 ; Steady and space variable wind speed
= 4 ; Time variable and uniform wind stress
= 5 ; Time variable and uniform wind speed
= 6 ; Time and space variable wind stress
= 7 ; Time and space variable wind speed
TAUX ; Uniform wind stress in x-direction if IWIND =0
Uniform wind speed in x-direction if IWIND=1
TAUY ; Uniform wind stress in y-direction if IWIND =0
Uniform wind speed in y-direction if IWIND=1

DUMMY
ISPAC(I), I=1,10 (10I8)

ISPAC(1) - ISPAC(3) = 0 (Not used)
ISPAC(4) = 1 ; Flag for computing open boundary velocities
ISPAC(5) - ISPAC(8) = 0 (Not used)
ISPAC(9) = 0 ; For IEXP = 0
= 1 ; For IEXP < 1
ISPAC(10) = 0 (Not used)

DUMMY
JSPAC(I), I=1,10 (10I8)

JSPAC(1) = 0 (Not used)
JSPAC(2) ; Flag for 3-D mode, quadratic friction
= 0 ; Constant bottom friction factor = CTB
= 1 ; Bottom friction based on logarithmic law
JSPAC(3) ; Flag for Coriolis terms
= 0 ; Coriolis effects accounted for
=-1 ; Coriolis effects neglected
JSPAC(4) - JSPAC(10) = 0 (Not used)

DUMMY
RSPAC(I), I=1,10 (10F8.0)
RSPAC(1) - RSPAC(6) = 0. (Not used)
RSPAC(7) ; Depth (cm) below which the bottom friction coefficient follows a ramp function
RSPAC(8) ; Dummy parameter (set to 0.008)
RSPAC(9) - RSPAC(10) = 0. (Not used)

DUMMY
IBTM, HADD, HMIN, H1, H2, SSS0, HMAX (I8,5F8.0)

IBTM	; Bottom bathymetry flag
IBTM = 0	; Bottom depth varies linearly from west to east of the basin
= 1	; Bottom depth varies linearly from south to north of the basin
= 2	; Bottom depth array for cell center depths read from input file (FILE 4)
= 3	; Bottom depth arrays HS, HU, HV read from FILE 12
= 4	; Bottom depths and coordinates of cell corners read from FILE 15 (set ITRAN=2)
HADD	; A constant depth added to the depth array (cm)
HMIN	; Minimum water depth (cm)
H1	; Bottom depth (cm) along the west or south boundary of the basin for IBTM = 0 or 1
H2	; Bottom depth (cm) along the east or north boundary of the basin for IBTM = 0 or 1
SSS0	; Initial water surface elevation (cm)
HMAX	; Maximum water depth (cm) allowed

DUMMY
ISMALL, ISF, ITB, ZREFBN, CTB, BZ1, ZREFTN, TZ1 (3I8,7F8.0)

ISMALL = 0	; Small amplitude assumption is invoked. Surface elevation is not added to the still water depth to obtain the total depth
= 1	; Small amplitude assumption is not invoked. Surface elevation is added to the still water depth to obtain the total depth
ISF = 0	: Free surface current flag (set to 0)
ITB	: Bottom friction flag
= 1	; Linear bottom friction for internal mode
> 1	; Quadratic bottom friction for internal mode
ZREFBN	; Reference height above bottom (cm)
CTB	; Constant bottom drag coefficient (typical value 0.003)
BZ1	; Bottom roughness height (cm)
ZREFTN	; Reference height at the top (cm)

TZ1 ; Constant surface roughness height (cm)

DUMMY
XMAP, ALXREF, ALYREF (10F8.0)

XMAP ; Mapping factor that scales the (x,y) coordinates created by the grid generation code to the real world
ALXREF ; X-reference length in the computational plane
ALYREF ; Y-reference length in the computational plane

Note : ALXREF and ALYREF are used if ITRAN = 0

DUMMY
ITRAN (10I8)

ITRAN = 0 ; Cartesian grid
= 1 ; Curvilinear grid created by WESCOR. Cell corner coordinates read from FILE 15
= 2 ; Curvilinear grid created by WESCORA or EAGLE. Cell corner coordinates and depths read from FILE 15

DUMMY
ITBRK(I), I=1,10 (10I8)

ITBRK(I), I=1,10; Time steps at which information is written to hot-start files (increasing order)

DUMMY
NSTA, NFREQ, NSTART (10I8)

NSTA ; Number of stations where information is saved for time series plots of currents
NFREQ ; Time step interval for saving currents
NSTART ; Beginning time step for saving currents

DUMMY
IST(K), JST(K), STATID(K) (2I4,A48)

If NSTA > 0, NSTA lines have to be furnished below.

IST(K), JST(K) ; Cell indices (I,J) of a station where currents are saved
STATID(K) ; Station descriptor

DUMMY
NSTAS, NFREQS, NSTRTS (10I8)

NSTAS ; Number of stations where water surface elevations are saved for time series plots
NFREQS ; Time step interval for saving water surface elevations

NSTRTS ; Beginning time step for saving water surface elevations

DUMMY
ISTS(K), JSTS(K), STATS(K) (2I4,A48)

If NSTAS > 0, NSTAS lines have to be furnished below.

ISTS(K),JSTS(K)	; Cell indices (I,J) of a station where water surface elevations are saved
STATS(K)	; Station descriptor

DUMMY
MSTA, MFREQ, MSTART (10I8)

MSTA	; Number of stations where salinity and temperature information is saved for time series plots
MFREQ	; Time step interval for saving information
MSTART	; Beginning time step for saving information

DUMMY
ISTSA(K), JSTSA(K), STATSA(K) (2I4,A48)

If MSTA > 0, MSTA lines have to be furnished below.

ISTSA(K),JSTSA(K)	; Cell indices (I,J) of a station where salinity and temperature are saved
STATSA(K)	; Station descriptor

DUMMY

NRIVER	; Number of river boundaries (2I8,F8.0,4I8)
NRIVER = 0	; No river boundaries
< 0	; River inflows are steady
> 0	; Time variable inflows

If NRIVER = 0, use the following lines

DUMMY
DUMMY

If NRIVER > 0, use the following lines

DUMMY
IJRDIR(K), IJRROW(K), IJRSTR(K), IJREND(K)* (10I8)

IJRDIR(K) = 1	; River boundary is on left (west)
= 2	; River boundary is on bottom (south)
= 3	; River boundary is on right (east)
= 4	; River boundary is on top (north)

IJRROW(K) ; Index of the row (J) or column (I) of the river boundary
IJRSTR(K) ; Starting I or J index of the river boundary
IJREND(K) ; Ending I or J index of the river boundary

* NRIVER lines have to be furnished

If NRIVER < 0, use the following lines

DUMMY
IJRDIR(K), IJRROW(K), IJRSTR(K), IJREND(K)* (10I8)
IJRDIR(K) = 1 ; River boundary is on left (west)
= 2 ; River boundary is on bottom (south)
= 3 ; River boundary is on right (east)
= 4 ; River boundary is on top (north)
IJRROW(K) ; Index of the row (J) or column (I) of the river boundary
IJRSTR(K) ; Starting I or J index of the river boundary
IJREND(K) ; Ending I or J index of the river boundary

*|NRIVER| lines have to be furnished followed by the lines shown below.

DUMMY
ICELL, JCELL, QRIVER(K,IJ)* (2I8,F8.0,4I8)
ICELL, JCELL ; Coordinates of a cell (I,J) where QRIVER is prescribed
QRIVER(K,IJ) ; Steady river inflow

*Repeat for all the river cells, in order.

DUMMY
NBAR (10I8)
NBAR ; Number of interior thin-wall barriers

If NBAR = 0, use the following line
DUMMY
If NBAR > 0, use the following lines

DUMMY
IJBDIR(K), IJBROW(K), IJBSTR(K), IJBEND(K)* (10I8)
IJBDIR(K) = 1 ; Barrier is in ξ-direction
= 2 ; Barrier is in η-direction
IJBROW(K) ; Index of row (J) or column (I) of barrier
IJBSTR(K) ; Starting I or J index of barrier
IJBEND(K) ; Ending I or J index of barrier

*NBAR lines have to be furnished.

DUMMY
TIDFNO, TIDBND (10I8)

TIDFNO	; Number of tidal elevation tables entered as input
TIDBND	; Number of tidal elevation boundaries

DUMMY
If TIDFNO > 0, read the following line(s)
TIDSTR(I), I=1,TIDFNO (10I8)

TIDSTR(I)	; The entry number in each tidal elevation table corresponding to the starting time of the simulation

DUMMY
If TIDBND > 0, TIDBND lines of the following format have to be read.
IJDIR(I), IJROW(I), IJSTR(I), IJEND(I), TIDTYP(I), TIDFN1(I), TIDFN2(I) (4I8,A8,5I8)

IJDIR(I) = 1	; Tidal boundary is on left (west)
= 2	; Tidal boundary is on bottom (south)
= 3	; Tidal boundary is on right (east)
= 4	; Tidal boundary is on top (north)
IJROW(I)	; Index of the row (J) or column (I) of the tidal boundary
IJSTR(I)	; Starting I or J index of the tidal boundary
IJEND(I)	; Ending I or J index of the tidal boundary
TIDTYP(I) = "CONSTANT"	; Constant tidal elevation between IJSTR(I) and IJEND(I)
= "INTERP"	; Linear interpolation of tidal elevation between IJSTR(I) and IJEND(I)
TIDFN1(I)	; The number of the tidal elevation table for CONSTANT or INTERP type of boundaries
TIDFN2(I)	; The number of the second tidal elevation table used for interpolation on INTERP type boundaries

Optional input:

DUMMY

I,J (4x,I2,1x,I2)	; Indices of a cell where HS is reset to 0.

DUMMY

I,J (4x,I2,1x,I2)	; Indices of a cell where HU is reset to 0.

DUMMY

I,J (4x,I2,1x,I2)	; Indices of a cell where HV is reset to 0.

DUMMY

I,J, RDEPTH (free format)	; Indices and depth (ft) of a cell where HS is reset to non-zero value RDEPTH.

Appendix C
List of Input Data Files[1]

FILE 13

River inflows are read from FILE 13. These data are read first as a time line (DAY and HOUR) formatted by 2I8. Next, the (I,J) location and discharge in cubic feet per second for each cell of each river boundary are read and formatted by (2I8, F8.0).

FILE 14

Wind data are read from FILE 14. These data are in the form of time (DAY and HOUR) and the x and y components of the wind velocity in meters per second of each wind field used. These data are formatted by (2I5,6F10.0).

FILE 15

The (x,y) coordinates and depths of the New York Bight grid cell corners are read from FILE 15. This file was created from a run of the grid generation code EAGLE and a depth interpolation program. The first line contains the file name formatted as A80. The number of corner points in ξ and η are read next unformatted. The coordinates and depths are read next unformatted, one line per corner.

FILE 16

Tabular tide data are read from FILE 16. The first line is the title formatted as A80. The tide data are in the form of time (MONTH, DAY, YEAR, HOUR, MINUTES) and the water surface elevations in centimeters relative to selected datum for TIDFNO points. These data are formatted by (I2,1X,2I3,1X,2I2,(T17,8F8.2)).

[1] A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page vi.

FILE 17

The initial temperature field in degrees Celsius is read from FILE 17 by format (10E12.5). This file is created from a few observed values. The resulting field is then smoothed in the ξ and η directions several times before it is written to FILE 17.

FILE 18

The Manning's roughness n is hard-wired in the model for the New York Bight application. By changing the source code, a field of Manning's n values may be input by format (20F4.0). The input values are multiplied by 0.001 in the source code to yield the actual values. They are input by rows.

FILE 19

Daily average equilibrium temperatures in degrees Celsius and surface heat exchange coefficients in units of cm/sec are read from FILE 19. These data are in the form of time (DAY and HOUR), equilibrium temperature, and heat exchange coefficient. They are formatted by (2I5,F10.0,E12.5).

FILE 74

The initial salinity field in parts per thousand is read from FILE 74 by format (10E12.5). This file is created in the same fashion as FILE 17.

FILE 76

Time-varying salinity in parts per thousand and temperature in degrees Celsius at tidal boundaries are read from FILE 76 if salinity and temperature are to be computed. These data are in the form of time (DAY and HOUR) formatted by (2I5). Next, the (I,J) location of each tidal boundary cell and the vertical distribution of salinity, starting from the top layer to the bottom layer are read. These data are followed by temperature data using the same format as for the salinity. The format is (2I5,11F5.0)

FILE 78

Time-varying temperature data at river flow boundaries are read from FILE 78 if temperatures are to be computed and equilibrium temperatures are not used as river boundary temperatures. These data are in the form of a time (DAY and HOUR) formatted by (2I5). Next, the (I,J) location of river flow boundary cells and corresponding temperatures starting from top layer to bottom layer are read. These data are formatted by (2I5,11F6.0).

FILE 85

This file contains corner point information for the water quality boxes (free formatted).

FILE 90

This one line file contains the time averaging interval (NAVG) and the starting time step (ITPTS) for saving information for input to the Particle Tracking Model (free formatted).

FILE 95

This file contains the number of surface boxes (NSB), the time averaging interval (NAVG), the time step to start saving information (ITWQS), WQMINT, WQMSTR, WQMEND, and WQMSNP (free format). It also has information on each of the surface boxes and each flow face.

Appendix D
Input Data in File 4 for April 1976 Application

```
TITLE(A80)
    NY BIGHT TEST : 76 X 45 GRID RERUN 18; IFD = 1; 3-D sa &te  30days 8-13-93
    IT1      IT2       DT  ISTART    ITEST  ITSALT
      1    17280    150.0       0        0    2880
  WPRCRD
      1
 WXCEL1   WXCEL2   WYCEL1   WYCEL2   WZCEL1   WZCEL2   WPRINT   WPRSTR   WPREND   WPRVAR
      1       76        1       45        1       10    17280    72800   100000 EST
 SNPCRD
      1
 SXCEL1   SXCEL2   SYCEL1   SYCEL2   SZCEL1   SZCEL2   SNPINT   SNPSTR   SNPEND   SNPVAR
      1       76        1       45        1       10    17280    72800   100000 EST
  NRANG
      2
 RANGDR    RPOS1    RPOS2    RPOS3   RRNAME
      X       40       40       40   EAST RIVER(WEST)
      X       44       40       40   EAST RIVER(EAST)
    IGI      IGH      IGT      IGS      IGU      IGW      IGC      IGQ      IGP
      0        0        0        0        0        0        0        0        0
   XREF     ZREF     UREF      COR       GR      RDO      ROR       TO       TR
521500.    9144.     10.0   .00009    981.0      1.0    1.021       1.      35.
  THETA
    1.0
  ITEMP    ISALT      ICC      IFI      IFA      IFB      IFC      IFD      AHO
     -2       -2        0        1        0        0        0        1  100000.
   IVIS      IWQ      IPT
      0        1        0
VISSTRF  VISENDF  VISINTF
VISSTRS  VISENDS  VISINTS
VISSTRT  VISENDT  VISINTT
    BVR       S1       S2       PR      PRV      TWE      TWH      FXB      TRO
    1.0      10.     3.33       1.      1.0      10.      10.       5.      0.0
   IVER     ICON     IUBO      IBL      IBR      JBM      JBP
      2        3        0        1       76        1       45
   CREF     CMAX       C0
     1.     100.       0.
   IIC1      IC2     JJC1      JC2      ID1      ID2      JD1      JD2
      0        0        0        0        0        0        0        0
```

```
  IEXP     IAV    AVR     AV1     AV2     AVM    AVM1     AHR
    -3       0    10.      0.      0.    10.0  0.005 100000.
   FM1     FM2   ZTOP   SLMIN   QQMIN
   -.5    -1.5     0.      1.    0.01
  ICUT  KSMALL   QCUT   GAMAX   GBMAX     FZS
     0       0   0.15   5000.   5000.     0.2
 IWIND    TAUX   TAUY
     5    0.00   0.00
 ISPAC(I),I=1,10
     0       0      0       1       0       0       1       0       1       0
 JSPAC(I),I=1,10
     1       1      0       0       0       0       0       1       0       0
 RSPAC(I),I=1,10
  .020      0. .00001  .00001      0.      1.   1000.   0.008     .25      4.
  IBTM    HADD   HMIN      H1      H2    SSS0    HMAX
     4      0.  304.8     0.0     0.0     0.0 999999.
ISMALL     ISF    ITB  ZREFBN     CTB     BZ1  ZREFBN     TZ1
     1       0      5      5.  0.0025   0.005      5.      .2
  XMAP  ALXREF ALYREF
 30.48  521500 747400
ITRAN   IBD(1)    (2)     (3)     (4)
     2       4      4       4       4
 ITBRK(1)   (2)     (3)     (4)     (5)     (6)     (7)     (8)     (9)    (10)
   70272  88128  105408      0       0       0       0       0       0       0
    NSTA  NFREQ  NSTART   (CURRENT STATIONS)
       8     48      0
 IST JST  STATID(K)    (2I4,A48)    ( ONE CARD FOR EACH STATION )
  37  15  MESA LT 1
   7  15  MESA LT 2
  11   6  MESA LT 3
  54  17  MESA LT 4
  52   9  MESA LT 5
  23  24  MESA LT 6
  40  42  HUDSON R. (40,42)
  38  41  HUDSON R. (38,41)
   NSTAS  NFREQS  NSTRTS   (TIDE STATIONS)
      13     48      0
 IST JST  STATID(K)    (2I4,A48)    ( ONE CARD FOR EACH STATION )
   4  25  ATLANTIC CITY (4,25)
  27  37  SANDY HOOK (27,37)
  39  41  THE BATTERY (39,41)
  62  37  NEW LONDON (62,37)
  68  43  NEWPORT (68,43)
  40  42  HUDSON R. (40,42)
  38  41  HUDSON R. (38,41)
  44  41  L.I. SOUND (44,41)
  33   7  OCEAN BDRY (33,7)
  75  33  (75,33)
  74  33  (74,33)
  75  35  (75,35)
  75  31  (75,31)
   MSTA  MFREQ  MSTART      (SALINITY STATIONS)
       7    144   2880
 IST JST  STATID(K)    (2I4,A48)    ( ONE CARD FOR EACH STATION )
  37  15  MESA LT 1 (37,15)
   7  15  MESA LT 2 (7,15)
  11   6  MESA LT 3 (11,6)
```

```
54  17  MESA LT 4 (54,17)
52   9  MESA LT 5 (52,9)
23  24  MESA LT 6 (23,24)
26  15  MESA LT 7 (26,15)
NRIVER
     1
IJRDIR  IJRROW  IJRSTR  IJREND    ( ONE CARD FOR EACH RIVER )
     3      40      42      42
     I       J  QRIVER            ( ONE CARD FOR EACH CELL )
  NBAR
     0
IJRDIR  IJRROW  IJRSTR  IJREND    ( ONE CARD FOR EACH BAR )
TIDFNO  TIDBND
    11       8
TIDSTR       2       3       4       5       6       7       8       9      10
     1       1       1       1       1       1       1       1       1       1
     I
  IJDIR   IJROW  IJSTRT   IJEND TIDTYP  TIDFN1  TIDFN2
     1       1       1       6INTERP       4       3
     1       1       6       8INTERP       3       2
     1       1       8      25INTERP       2       1
     2       1       1      10INTERP       4       5
     2       1      10      32INTERP       5       6
     2       1      32      60INTERP       6       7
     2       1      60      76INTERP       7       7
     3      76       1      43INTERP       7      11
RESET HS(I,J) TO ZERO AT THE FOLLOWING CELLS
    24,45
    61,26
    62,26
    63,27
    58,30
    59,30
    66,30
    59,31
    60,32
    52,33
    26,36
    27,36
    71,36
    28,37
    34,37
    35,37
    64,37
    71,37
    72,37
    62,38
    72,38
    35,39
    44,39
    45,39
    46,39
    47,39
    72,39
    72,40
    40,41
    41,41
```

```
42,41
43,41
35,42
36,42
41,42
42,42
43,42
49,43
50,43
51,43
52,43
53,43
54,43
56,43
RESET HU(I,J) TO ZERO AT THE FOLLOWING CELLS
61,26
62,26
59,30
26,36
27,36
35,37
36,37
72,37
63,38
36,39
44,39
45,39
46,39
47,39
41,41
42,41
43,41
36,42
42,42
43,42
50,43
51,43
52,43
53,43
54,43
57,43
RESET HV(I,J) TO ZERO AT THE FOLLOWING CELLS
59,31
52,33
71,37
64,38
72,38
44,39
45,39
46,39
47,39
62,39
72,39
72,40
35,43
36,43
49,44
50,44
```

```
    51,44
    52,44
    53,44
    54,44
    56,44
RESET HS(I,J) TO THE FOLLOWING DEPTHS
   STORAGE AREAS
   END OF DATA
   END OF FILE
```

Appendix E
River Inflows in File 13

```
   0      0           Original Data Date 04/01/76
  40     42 -55500.
   1      0
  40     42 -99900.
   2      0
  40     42 -80600.
   3      0
  40     42 -66000.
   4      0
  40     42 -53900.
   5      0
  40     42 -46000.
   6      0
  40     42 -40800.
   7      0
  40     42 -36400.
   8      0
  40     42 -33100.
   9      0
  40     42 -31500.
  10      0
  40     42 -31200.
  11      0
  40     42 -30000.
  12      0
  40     42 -27400.
  13      0
  40     42 -24400.
  14      0
  40     42 -23400.
  15      0
  40     42 -22900.
  16      0
  40     42 -30000.
  17      0
  40     42 -30800.
  18      0
  40     42 -29000.
  19      0
  40     42 -27200.
  20      0
  40     42 -27100.
  21      0
  40     42 -24400.
  22      0
```

Appendix F
Wind Data in File 14

0	0	-4.745	0.080	-5.165	5.655	-5.550	4.175
0	6	-5.825	3.270	-6.425	7.505	-4.215	7.415
0	12	-6.375	9.670	-7.420	9.255	-0.770	10.425
0	18	-2.690	10.980	2.320	4.315	6.340	4.720
1	0	-0.210	6.150	3.410	1.620	3.645	1.340
1	6	2.990	0.330	4.905	1.215	4.765	0.660
1	12	2.860	-1.620	3.035	-1.165	3.425	-1.765
1	18	2.440	-0.615	3.520	-1.640	4.515	-1.670
2	0	1.875	-2.640	3.325	-6.880	5.200	-6.595
2	6	5.800	-9.530	6.450	-10.430	7.610	-12.375
2	12	10.130	-11.370	9.830	-11.270	10.640	-12.920
2	18	12.450	-10.640	11.270	-9.200	12.295	-8.345
3	0	10.485	-9.780	9.920	-7.315	12.700	-4.390
3	6	10.805	-9.065	7.970	-4.480	8.525	-6.940
3	12	10.840	-4.395	4.210	-1.115	6.645	2.870
3	18	6.820	-0.280	0.280	-0.275	5.145	5.945
4	0	4.125	1.540	0.790	-5.300	2.940	1.825
4	6	7.315	-5.945	5.585	-11.920	4.640	-8.580
4	12	11.105	-8.605	11.070	-10.585	6.700	-12.160
4	18	14.455	-6.010	12.910	-5.980	9.510	-7.545
5	0	12.695	1.205	10.825	1.565	8.750	1.455
5	6	10.175	1.835	8.500	2.470	6.440	3.250
5	12	8.055	2.210	7.205	2.130	6.400	3.445
5	18	7.050	4.465	6.140	2.950	4.610	3.895
6	0	7.000	4.500	5.485	3.520	3.955	4.180
6	6	4.215	0.020	3.290	-2.485	2.755	0.260
6	12	4.350	-0.650	3.020	-4.515	0.510	-3.050
6	18	4.050	-4.325	3.695	-5.050	0.990	-4.595
7	0	4.250	-2.655	3.135	-1.865	-0.315	-2.605
7	6	0.685	-3.330	-0.355	-2.640	-0.770	-2.245
7	12	-0.210	-0.320	-0.795	-1.735	-2.340	-0.520
7	18	-0.920	1.220	-1.110	-1.240	-3.510	0.555
8	0	-3.490	1.240	-3.565	-1.935	-5.885	-2.110
8	6	-6.495	-4.030	-4.490	-6.110	-7.495	-6.630
8	12	-10.660	-7.735	-9.020	-10.890	-10.200	-13.940
8	18	-11.420	-9.410	-8.025	-11.670	-6.065	-17.790
9	12	2.725	-18.945	1.525	-15.975	5.470	-15.945
9	18	9.625	-15.805	9.840	-10.315	9.725	-12.490
10	0	13.495	-2.725	11.695	-2.285	8.610	-7.430
10	6	15.765	0.410	12.635	1.810	13.730	2.500
11	0	4.850	-4.080	5.505	-9.045	6.545	0.125
11	6	5.220	-12.870	4.600	-13.785	1.145	-10.515
11	12	5.695	-13.495	5.825	-12.990	4.335	-14.300
11	18	8.415	-10.445	9.600	-10.380	7.875	-10.510
12	0	8.495	-6.250	9.775	-6.485	8.080	-5.585

Appendix G
Cell Corner Coordinates and Depths in File 15[1]

NYB 76X45 GRID COORDINATES AND CELL CORNER DEPTHS IN FEET

77	46	
685640.00	86328.00	2871.58
712180.00	134440.00	1102.72
739020.00	175750.00	845.24
768800.00	209820.00	1064.46
794390.00	239720.00	811.28
819210.00	262880.00	696.21
838940.00	284560.00	922.45
856720.00	302050.00	1050.65
870360.00	317240.00	1767.19
883560.00	328250.00	2042.94
894500.00	338390.00	1307.50
907120.00	348440.00	1464.82
920590.00	359190.00	1394.77
934740.00	370350.00	2398.77
949350.00	381260.00	1630.39
964000.00	391580.00	2198.52
979940.00	400390.00	1998.72
993410.00	409090.00	1601.43
1007400.00	417370.00	2024.36
1019600.00	425990.00	1485.39
1030700.00	433970.00	1898.15
1040500.00	441280.00	1662.43
1049300.00	447660.00	1643.20
1056500.00	453770.00	3408.01
1062200.00	459810.00	2390.16
1066700.00	465600.00	2530.58
1070900.00	471180.00	3874.83
1075700.00	476150.00	3357.38
1080400.00	480840.00	3540.52
1085600.00	485320.00	2694.58
1090700.00	490050.00	3639.25
1095900.00	494570.00	4632.64
1100200.00	499590.00	3921.73
1105400.00	504250.00	2999.45
1109600.00	509590.00	2682.54
1114300.00	514710.00	1953.10
1119200.00	519800.00	2162.94
1124300.00	524940.00	2647.65
1130300.00	530120.00	2342.08
1135900.00	536300.00	2228.55

[1] A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page vi.

Appendix H
Tabular Tide in File 16

New York Bight : 8 - Constituents Tide 4/01/76 - 9/30/76

4 1 76 0 0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00					
4 1 76 030	-39.56	-34.41	-33.85	-32.72	-33.01	-30.86	-28.67	-26.86
	-26.85	-26.86	-31.15					
4 1 76 1 0	-49.44	-42.68	-41.95	-40.35	-40.79	-38.45	-36.15	-35.05
	-35.19	-35.28	-41.09					
4 1 76 130	-55.99	-48.03	-47.19	-45.25	-45.79	-43.40	-41.12	-40.85
	-41.12	-41.30	-48.22					
4 1 76 2 0	-58.83	-50.14	-49.25	-47.13	-47.74	-45.43	-43.30	-43.92
	-44.30	-44.55	-52.12					
4 1 76 230	-57.82	-48.94	-48.06	-45.92	-46.57	-44.46	-42.60	-44.10
	-44.57	-44.87	-52.58					
4 1 76 3 0	-53.04	-44.53	-43.74	-41.74	-42.40	-40.60	-39.10	-41.42
	-41.95	-42.28	-49.59					
4 1 76 330	-44.90	-37.26	-36.61	-34.90	-35.54	-34.15	-33.09	-36.10
	-36.66	-37.00	-43.43					
4 1 76 4 0	-33.92	-27.65	-27.19	-25.91	-26.49	-25.59	-25.01	-28.53
	-29.09	-29.42	-34.53					
4 1 76 430	-20.94	-16.37	-16.13	-15.38	-15.89	-15.52	-15.43	-19.26
	-19.77	-20.08	-23.50					
4 1 76 5 0	-6.80	-4.19	-4.20	-4.05	-4.48	-4.66	-5.03	-8.92
	-9.36	-9.61	-11.09					
4 1 76 530	7.56	8.05	7.79	7.32	6.97	6.26	5.47	1.77
	1.43	1.24	1.80					
4 1 76 6 0	21.12	19.50	18.99	17.92	17.65	16.46	15.32	12.06
	11.84	11.73	14.33					
4 1 76 630	33.01	29.41	28.69	27.08	26.88	25.28	23.89	21.29
	21.21	21.17	25.66					
4 1 76 7 0	42.43	37.09	36.21	34.16	34.00	32.09	30.56	28.81
	28.87	28.91	35.02					
4 1 76 730	48.71	42.03	41.03	38.68	38.54	36.43	34.88	34.13
	34.31	34.43	41.79					
4 1 76 8 0	51.45	43.88	42.83	40.33	40.19	37.99	36.54	36.87
	37.17	37.36	45.51					
4 1 76 830	50.51	42.50	41.48	38.99	38.83	36.67	35.43	36.85
	37.24	37.48	45.90					
4 1 76 9 0	45.87	37.99	37.06	34.76	34.55	32.56	31.61	34.08
	34.54	34.82	43.01					
4 1 76 930	37.92	30.64	29.86	27.91	27.63	25.91	25.33	28.75
	29.24	29.53	36.97					
4 1 76 10 0	27.16	20.94	20.37	18.90	18.55	17.18	17.01	21.21
	21.70	21.98	28.19					
4 1 76 1030	14.33	9.52	9.20	8.34	7.90	6.94	7.21	11.97
	12.43	12.68	17.31					

Appendix I
Initial Temperature Field in File 17

0.00000E+00	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02
0.12500E+02	0.12600E+02	0.12600E+02	0.12600E+02	0.12600E+02	0.12700E+02	0.12700E+02	0.12700E+02	0.12700E+02	0.12700E+02
0.12700E+02	0.12700E+02	0.12700E+02	0.12600E+02	0.12600E+02	0.12600E+02	0.12300E+02	0.12300E+02	0.11900E+02	0.99000E+01
0.83000E+01	0.84000E+01	0.98000E+01	0.11200E+02	0.12300E+02	0.12300E+02	0.11900E+02	0.12300E+02	0.12600E+02	0.12700E+02
0.12600E+02	0.12600E+02	0.12600E+02	0.12600E+02	0.12400E+02	0.12400E+02	0.12600E+02	0.12600E+02	0.12600E+02	0.12600E+02
0.12500E+02	0.12400E+02	0.12500E+02	0.12600E+02	0.12600E+02	0.12500E+02	0.12600E+02	0.12700E+02	0.12700E+02	0.12600E+02
0.12500E+02	0.12300E+02	0.12100E+02	0.11900E+02	0.11600E+02	0.11700E+02	0.11700E+02	0.11800E+02	0.12100E+02	0.12300E+02
0.12300E+02	0.12300E+02	0.12000E+02	0.11900E+02	0.12000E+02	0.12200E+02	0.12000E+02	0.00000E+00	0.00000E+00	0.12500E+02
0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02	0.12500E+02
0.12600E+02	0.12600E+02	0.12600E+02	0.12600E+02	0.12700E+02	0.12700E+02	0.12700E+02	0.12700E+02	0.12700E+02	0.12700E+02
0.12700E+02	0.12700E+02	0.12600E+02	0.12600E+02	0.12600E+02	0.12300E+02	0.12300E+02	0.11900E+02	0.99000E+01	0.83000E+01
0.84000E+01	0.98000E+01	0.11200E+02	0.12300E+02	0.12300E+02	0.11900E+02	0.12300E+02	0.12600E+02	0.12700E+02	0.12600E+02
0.12600E+02	0.12600E+02	0.12600E+02	0.12400E+02	0.12400E+02	0.12600E+02	0.12600E+02	0.12600E+02	0.12600E+02	0.12500E+02
0.12400E+02	0.12500E+02	0.12600E+02	0.12600E+02	0.12500E+02	0.12600E+02	0.12700E+02	0.12700E+02	0.12600E+02	0.12500E+02
0.12300E+02	0.12100E+02	0.11900E+02	0.11800E+02	0.11700E+02	0.11700E+02	0.11800E+02	0.12100E+02	0.12300E+02	0.12300E+02
0.12300E+02	0.12000E+02	0.11900E+02	0.12000E+02	0.12200E+02	0.12000E+02	0.12000E+02	0.12000E+02	0.12500E+02	0.12500E+02
0.12264E+02	0.12215E+02	0.12182E+02	0.12092E+02	0.11939E+02	0.11760E+02	0.11599E+02	0.11484E+02	0.11432E+02	0.11481E+02
0.11549E+02	0.11644E+02	0.11744E+02	0.11872E+02	0.11954E+02	0.12021E+02	0.12070E+02	0.12099E+02	0.12102E+02	0.12067E+02
0.11983E+02	0.11840E+02	0.11741E+02	0.11661E+02	0.11502E+02	0.11399E+02	0.10959E+02	0.98345E+01	0.89857E+01	0.90401E+01
0.98101E+01	0.10688E+02	0.11395E+02	0.11593E+02	0.11608E+02	0.11893E+02	0.12111E+02	0.12213E+02	0.12217E+02	0.12237E+02
0.12241E+02	0.12225E+02	0.12142E+02	0.12152E+02	0.12238E+02	0.12244E+02	0.12241E+02	0.12227E+02	0.12180E+02	0.12154E+02
0.12220E+02	0.12288E+02	0.12316E+02	0.12322E+02	0.12411E+02	0.12493E+02	0.12510E+02	0.12459E+02	0.12373E+02	0.12223E+02
0.12059E+02	0.11899E+02	0.11790E+02	0.11713E+02	0.11715E+02	0.11802E+02	0.11980E+02	0.12099E+02	0.12098E+02	0.12025E+02
0.11799E+02	0.11647E+02	0.11603E+02	0.11644E+02	0.11700E+02	0.11700E+02	0.11700E+02	0.12500E+02	0.12500E+02	0.11591E+02
0.11695E+02	0.11708E+02	0.11554E+02	0.11265E+02	0.10931E+02	0.10635E+02	0.10421E+02	0.10312E+02	0.10335E+02	0.10445E+02
0.10665E+02	0.10771E+02	0.10936E+02	0.11070E+02	0.11180E+02	0.11258E+02	0.11303E+02	0.11308E+02	0.11252E+02	0.11128E+02
0.10956E+02	0.10811E+02	0.10711E+02	0.10624E+02	0.10534E+02	0.10215E+02	0.95798E+01	0.91046E+01	0.91206E+01	0.95623E+01
0.10141E+02	0.10657E+02	0.10940E+02	0.11119E+02	0.11363E+02	0.11555E+02	0.11681E+02	0.11755E+02	0.11817E+02	0.11855E+02
0.11866E+02	0.11848E+02	0.11864E+02	0.11898E+02	0.11886E+02	0.11849E+02	0.11795E+02	0.11732E+02	0.11703E+02	0.11732E+02
0.11781E+02	0.11838E+02	0.11920E+02	0.12057E+02	0.12192E+02	0.12278E+02	0.12300E+02	0.12265E+02	0.12168E+02	0.12039E+02
0.11904E+02	0.11796E+02	0.11724E+02	0.11720E+02	0.11787E+02	0.11904E+02	0.11979E+02	0.11951E+02	0.11811E+02	0.11550E+02
0.11300E+02	0.11123E+02	0.11044E+02	0.11100E+02	0.11100E+02	0.11100E+02	0.98000E+01	0.98000E+01	0.10643E+02	0.10997E+02
0.11082E+02	0.10886E+02	0.10503E+02	0.10072E+02	0.96967E+01	0.94187E+01	0.92536E+01	0.92518E+01	0.93940E+01	0.95955E+01
0.97979E+01	0.99838E+01	0.10140E+02	0.10263E+02	0.10349E+02	0.10397E+02	0.10400E+02	0.10342E+02	0.10217E+02	0.10054E+02
0.99105E+01	0.98215E+01	0.97763E+01	0.97243E+01	0.95321E+01	0.91794E+01	0.89102E+01	0.89119E+01	0.91783E+01	0.95740E+01
0.99696E+01	0.10261E+02	0.10483E+02	0.10699E+02	0.10879E+02	0.11030E+02	0.11159E+02	0.11277E+02	0.11372E+02	0.11438E+02
0.11476E+02	0.11504E+02	0.11506E+02	0.11452E+02	0.11348E+02	0.11213E+02	0.11080E+02	0.10992E+02	0.10965E+02	0.10986E+02
0.11060E+02	0.11204E+02	0.11420E+02	0.11657E+02	0.11864E+02	0.12008E+02	0.12076E+02	0.12064E+02	0.11995E+02	0.11895E+02
0.11798E+02	0.11730E+02	0.11719E+02	0.11770E+02	0.11854E+02	0.11891E+02	0.11809E+02	0.11576E+02	0.11217E+02	0.10843E+02
0.10539E+02	0.10347E+02	0.10300E+02	0.10300E+02	0.10300E+02	0.90000E+01	0.90000E+01	0.98495E+01	0.10278E+02	0.10366E+02
0.10133E+02	0.97121E+01	0.92597E+01	0.88774E+01	0.85865E+01	0.83416E+01	0.81888E+01	0.84736E+01	0.87350E+01	0.89618E+01
0.91527E+01	0.93082E+01	0.94273E+01	0.95072E+01	0.95494E+01	0.95512E+01	0.95023E+01	0.94013E+01	0.92722E+01	0.91597E+01

Appendix J
Equilibrium Temperature and Surface Heat Exchange Coefficient in File 19

0	0	5.92000	0.80782E-03
1	0	9.50000	0.13752E-02
2	0	11.78000	0.72274E-03
3	0	9.41000	0.97871E-03
4	0	10.89000	0.58029E-03
5	0	7.37000	0.12215E-02
6	0	12.83000	0.66323E-03
7	0	12.17000	0.71294E-03
8	0	10.90000	0.58627E-03
9	0	8.88000	0.80113E-03
10	0	8.79000	0.74807E-03
11	0	11.52000	0.86637E-03
12	0	2.64000	0.89744E-03
13	0	8.38000	0.75715E-03
14	0	14.23000	0.60228E-03
15	0	15.27000	0.60419E-03
16	0	16.29000	0.50118E-03
17	0	22.11000	0.56547E-03
18	0	18.25000	0.13458E-02
19	0	18.16000	0.10136E-02
20	0	21.88000	0.67685E-03
21	0	19.27000	0.72728E-03
22	0	16.35000	0.77030E-03
23	0	18.34000	0.97082E-03
24	0	12.60000	0.10420E-02
25	0	11.50000	0.11441E-02
26	0	10.30000	0.80017E-03
27	0	7.79000	0.10492E-02
28	0	11.09000	0.89434E-03
29	0	12.92000	0.84630E-03
30	0	17.57000	0.67063E-03
31	0	12.64000	0.11663E-02
32	0	16.89000	0.10174E-02
33	0	16.53000	0.88597E-03
34	0	11.08000	0.91083E-03
35	0	13.49000	0.99233E-03
36	0	16.79000	0.98062E-03
37	0	16.28000	0.99567E-03
38	0	12.69000	0.92397E-03
39	0	10.96000	0.95982E-03
40	0	16.58000	0.91131E-03

Appendix K
Time-Varying Vertical Distributions of Salinity and Temperature at the Ocean Boundary in File 76

61	0										
1	1	32.7	33.6	34.1	34.4	34.7	34.9	35.1	35.2	35.2	35.3
1	1	16.9	15.8	15.2	15.0	14.8	14.3	13.8	13.4	13.0	12.7
1	2	32.7	33.6	34.1	34.4	34.7	34.9	35.1	35.2	35.2	35.3
1	2	16.9	15.8	15.2	15.0	14.8	14.3	13.8	13.4	13.0	12.7
1	3	32.7	33.6	34.1	34.4	34.7	34.9	35.1	35.2	35.2	35.3
1	3	16.9	15.8	15.2	15.0	14.8	14.3	13.8	13.4	13.0	12.7
1	4	32.4	32.8	33.2	33.5	33.7	33.9	34.0	34.2	34.3	34.3
1	4	16.7	15.9	15.4	14.8	13.3	12.0	11.0	10.6	10.4	10.3
1	5	32.3	32.5	32.9	33.2	33.4	33.5	33.6	33.8	34.0	34.0
1	5	16.6	15.9	15.4	14.7	12.8	11.2	10.0	9.6	9.5	9.4
1	6	32.2	32.3	32.6	32.9	33.1	33.2	33.3	33.5	33.7	33.7
1	6	16.5	16.0	15.5	14.6	12.5	10.6	9.3	9.0	8.9	8.8
1	6	32.2	32.3	32.6	32.9	33.1	33.2	33.3	33.5	33.7	33.7
1	6	16.5	16.0	15.5	14.6	12.5	10.6	9.3	9.0	8.9	8.8
1	7	32.1	32.2	32.5	32.7	32.9	33.0	33.1	33.3	33.5	33.5
1	7	16.5	16.0	15.5	14.6	12.4	10.5	9.1	8.6	8.5	8.4
1	8	32.0	32.1	32.3	32.6	32.7	32.8	32.9	33.1	33.3	33.4
1	8	16.5	16.1	15.6	14.7	12.5	10.7	9.3	8.7	8.4	8.2
1	8	32.0	32.1	32.3	32.6	32.7	32.8	32.9	33.1	33.3	33.4
1	8	16.5	16.1	15.6	14.7	12.5	10.7	9.3	8.7	8.4	8.2
1	9	32.0	32.0	32.2	32.4	32.5	32.7	32.8	33.0	33.2	33.3
1	9	16.5	16.1	15.7	14.8	12.9	11.2	9.8	9.0	8.6	8.1
1	10	32.0	32.0	32.1	32.3	32.4	32.5	32.7	32.9	33.0	33.2
1	10	16.4	16.2	15.8	15.0	13.4	11.9	10.6	9.6	9.0	8.3
1	11	32.0	32.0	32.1	32.2	32.3	32.4	32.6	32.7	32.7	33.1
1	11	16.4	16.2	16.0	15.2	14.0	12.8	11.5	10.5	9.5	8.6
1	12	32.0	32.0	32.0	32.2	32.2	32.3	32.4	32.6	32.7	32.9
1	12	16.4	16.3	16.1	15.6	14.7	13.7	12.5	11.4	10.2	9.0
1	13	32.0	32.0	32.0	32.1	32.1	32.2	32.3	32.5	32.6	32.8
1	13	16.5	16.4	16.3	15.9	15.3	14.4	13.2	12.2	10.9	9.6
1	14	31.9	31.9	31.9	32.0	32.0	32.2	32.3	32.4	32.5	32.7
1	14	16.6	16.6	16.5	16.3	15.8	14.9	13.7	12.8	11.6	10.4
1	15	31.9	31.9	31.9	31.9	31.9	32.1	32.3	32.4	32.5	32.6
1	15	16.8	16.8	16.8	16.6	16.3	15.2	13.9	13.2	12.2	11.1
1	16	31.8	31.8	31.8	31.9	31.9	32.1	32.3	32.4	32.4	32.5
1	16	17.0	17.1	17.0	16.9	16.6	15.3	13.9	13.4	12.6	11.8
1	17	31.8	31.8	31.8	31.8	31.8	32.1	32.3	32.4	32.4	32.5
1	17	17.2	17.2	17.2	17.1	16.9	15.4	13.9	13.6	13.0	12.4
1	18	31.8	31.8	31.8	31.8	31.8	32.1	32.3	32.3	32.3	32.4
1	18	17.3	17.3	17.3	17.2	17.0	15.5	14.1	13.9	13.5	13.0
1	19	31.7	31.7	31.7	31.8	31.8	32.0	32.2	32.2	32.2	32.3
1	19	17.3	17.3	17.3	17.2	17.0	15.7	14.5	14.3	14.1	13.7
1	20	31.8	31.8	31.8	31.8	31.8	32.0	32.1	32.1	32.1	32.2
1	20	17.3	17.3	17.2	17.1	17.0	16.0	15.0	14.9	14.7	14.5
1	21	31.8	31.8	31.8	31.8	31.8	31.9	32.0	32.0	32.0	32.1
1	21	17.3	17.2	17.2	17.0	16.9	16.2	15.5	15.4	15.3	15.1
1	22	31.8	31.8	31.8	31.8	31.8	31.9	31.9	31.9	31.9	32.0
1	22	17.3	17.2	17.1	16.9	16.9	16.4	16.0	15.8	15.8	15.6
1	23	31.8	31.8	31.8	31.8	31.8	31.8	31.9	31.9	31.9	32.0
1	23	17.2	17.1	17.1	16.9	16.8	16.5	16.2	16.1	16.1	16.0
1	24	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.9
1	24	17.2	17.1	17.0	16.8	16.8	16.6	16.4	16.3	16.3	16.2
1	25	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.9
1	25	17.2	17.1	17.0	16.8	16.8	16.7	16.6	16.5	16.5	16.4
1	1	32.7	33.6	34.1	34.4	34.7	34.9	35.1	35.2	35.2	35.3
1	1	16.9	15.8	15.2	15.0	14.8	14.3	13.8	13.4	13.0	12.7
2	1	32.6	33.5	34.0	34.3	34.6	34.8	34.9	35.1	35.2	35.2
2	1	17.0	16.0	15.3	15.1	15.0	14.6	14.2	13.7	13.3	13.0
3	1	32.6	33.5	34.0	34.3	34.6	34.8	34.9	35.1	35.2	35.2

Appendix L
Time-Varying Vertical Distribution of Temperature at the River Boundary in File 78

0	0										
40	42	7.5	7.55	7.6	7.59	7.58	7.56	7.55	7.54	7.52	7.51
61	0										
40	42	17.2	17.1	17.0	16.8	16.8	16.7	16.6	16.5	16.5	16.4
122	0										
40	42	22.7	22.7	22.7	22.7	22.7	22.1	21.2	20.2	18.5	16.6
153	0										
40	42	22.5	21.6	21.2	21.0	21.0	21.0	21.0	20.8	20.6	20.6
183	0										
40	42	22.5	21.6	21.2	21.0	21.0	21.0	21.0	20.8	20.6	20.6

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13. ABSTRACT *(Maximum 200 words)*

As a part of the New York (NY) Bight Feasibility Study, a three-dimensional, time-varying numerical hydrodynamic and transport model of the NY Bight was developed by the U.S. Army Engineer Waterways Experiment Station. For this purpose, the three-dimensional hydrodynamic model CH3D-WES was used, along with a boundary-fitted grid in the horizontal and 5-10 sigma layers in the vertical. The model was calibrated and verified with the field data measured in April and May 1976. As a demonstration of the feasibility of long-term simulation, hydrodynamics and transport were modeled for the period April - October 1976. Model results were furnished as input to a water quality model of the NY Bight, which reproduced successfully the hypoxic event of 1976.

This user's reference manual presents a brief description of the theory of the numerical model and its various features. The structure of the computer code, the function of various subroutines, the formats of input data, various data files required, and available output options are described in detail. For illustrative purposes, sample listings of input files are furnished for an example case simulating hydrodynamics and transport in the NY Bight for the month of April 1976.

14. SUBJECT TERMS

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Model	Three-dimensional	Water quality

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